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ABSTRACT

Worcester Polytechnic Institute (WPI), following two and one half years of intensive study and planning, has developed and begun the implementation of a PLAN for a new and comprehensively different educational program, responsive to the needs of individual students, society, and encouraging sensitivity to the ideas and values of civilization. In May 1972, the National Science Foundation's Directorate for Science Education through its program, Restructuring the Undergraduate Learning Environment (RULE), granted WPI the prototype award for this program. The purpose of this document is to transmit to the public one of the products of that project. The grant included several provisions for external evaluation of the program; one of these evaluations being based upon periodic reports of a visiting committee of several representatives from the fields of education, science, engineering, and industry. During the years 1972-75, the committee periodically observed and reacted to WPI's process of change. The reports contained in this publication are the first WPI-NSF Advisory Committee members' summary assessments of the project. Included in the appendix is a partial summary of papers, publications and news stories published to date. (BT)

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RESTRUCTURING UNDERGRADUATE SCIENCE EDUCATION

A Summative Assessment by the NSF-Worcester Polytechnic Institute Project Advisory Committee Constituted from 1972-75

Project Report No. 1

Report prepared for
NATIONAL SCIENCE FOUNDATION
DIRECTORATE FOR SCIENCE EDUCATION
Restructuring the Undergraduate Learning Environment
Under Grant Number GY-9353

SE 021 240

Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

AUG 0 3 1976

RESTRUCTURING UNDERGRADUATE SCIENCE EDUCATION AT WORCESTER POLYTECHNIC INSTITUTE WORCESTER, MASSACHUSETTS

A Summative Assessment by the NSF-WPI Project Advisory Committee Constituted from 1972-75

Project Report No. 1

Dr. Lee Harrisberger
Dr. Bruce Mazlish
Dr. George Pake
Dr. Kenneth Picha
Dr. Eugene D. Reed
Dr. David Riesman
Dr. John R. Whinnery

Report prepared for
NATIONAL SCIENCE FOUNDATION
DIRECTORATE FOR SCIENCE EDUCATION
Restructuring the Undergraduate Learning Environment
Under Grant Number GY-9353

INTRODUCTION

In 1968 Worcester Polytechnic Institute undertook a major educational planning effort which led two years later to the adoption by the faculty of a new academic philosophy and the accompanying systematic program redesign which differs markedly from the traditional approach to the education of engineers and scientists. The new program has become known as the WPI Plan.[1] With the total resources of the College committed, WPI since 1970 has been embarked on a seven-year implementation program placing extreme demands on all concerned.

WPI has received financial assistance for the program from many sources, but the largest grant has been from the National Science Foundation which, in May 1972 awarded WPI $730,400 later augmented to $1,211,500. The grant included several provisions for external evaluation of the program, one of these evaluations being based upon the periodic reports of a visiting committee of seven distinguished representatives from the fields of education, science, engineering and industry.[2]

For a period of three years every November and every April this group known as the NSF-WPI Advisory Panel, on each visit spent two to three days on the campus probing every aspect of the new program and submitting interim reports to NSF and WPI.

The final visit of the Panel took place in April 1975. Their final individual reports summarizing their observations over three years follow in alphabetical order of authorship.

The task of implementation at WPI is far from over. A new NSF grant provides for a new Panel for the next three years. To the members of this original Panel who have with a sense of personal dedication and astute, impartial criticism accompanied us through three of the most critical, exhausting and yet emotionally exciting years of WPI history, we are deeply grateful.

William R. Grogan
William R. Grogan
Dean of Undergraduate Studies
NSF Project Director
July 1975

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[1] To assist readers who may not be familiar with the scope and objectives of the WPI Plan the appendix contains a copy of my report presented March 6, 1975 to the Advisory Committee for Science Education of the National Science Foundation.

[2] A list of panel members is on the next page.

NSF-WPI ADVISORY PANEL

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FOREWORD

The National Science Foundation's Directorate for Science Education through its program, Restructuring the Undergraduate Learning Environment (RULE), is supporting a limited number of projects at institutions that are undertaking major changes in their undergraduate instructional programs in the sciences. In May 1972, Grant GY-9353, the prototpye award for this program, was made to Worcester Polytechnic Institute, Worcester, Massachusetts. The purpose of this document is to transmit to the public one of the products of that project.

The Foundation's purpose in RULE is to encourage colleges and universities and their science faculties in the development, testing, and evaluation of new or unconventional approaches to the organization, management, delivery, and/or content of undergraduate science education. Awards under RULE for projects which are comprehensive or institutional in scope, are based on the presumption that some of the problems confronting institutions of higher learning require a systematic, rather than fragmented approach. Projects which are directed at altering the basic structures of science programs and which are determined to have the greatest potential for increasing nationally the diversity of institutional settings for science receive priority in consideration for support.

The objectives of the Worcester Polytechnic Institute's restructuring project, for which NSF and other agencies both public and private have provided support, are summarized by the institution in its original proposal as follows:

> Worcester Polytechnic Institute following two and one half years of intensive study and planning, has developed and begun the implementation of a PLAN for a new and comprehensively different educational program, responsive to the needs of individual students, responsive to the needs of society, and encouraging sensitivity to the ideas and values of civilization. The PLAN involves a complete change in every aspect of campus activities, affecting every member of the faculty, every student, and every administrator.
>
> Since this major educational enterprise, involving total reorientation of an entire college, will require significant investment over the next several years, WPI now requests the assistance of the National Science Foundation and the National Endowment for Humanities, in developing itself as a model college, featuring: 1. Degree requirements measuring the achievement of competence rather than accumulation of academic credits. 2. Individual freedom in the planning of the educational process rather than a rigid prescribed curriculum. 3. A large component of self-initiated investigation rather than passive classroom participation. 4. New instructional methods emphasizing education as a cooperative venture between students and faculty, rather than the more frequent relationship of mutual antagonism.

> The PLAN emphasizes programs with concentration in science or engineering, containing a unique prescription for the integration of the humanities into the total educational experience, and programs with concentration in humanities or social science requiring demonstration of significant competence in science and engineering.
>
> WPI is now totally committed to an innovative model program which will not only demonstrate the educational effectiveness and financial feasibility of a new approach to scientific, technological and humanistic education, but will also add to the national experience in methodology of affecting major reform in established institutions of higher learning.

The Foundation's intentions in awarding this grant were to assist WPI in implementing its plan for total restructuring of its undergraduate program in the sciences, to help insure that the resultant project could be observed and studied as a model, and to provide to all interested parties some insight into the process of institutional change.

Several modes of evaluation have been and continue to be employed to assess the nature and impact of the events that have been occurring at WPI. An especially useful and challenging collection of insights has been provided by a committee of seven prominent figures in science, in education, and in industry who, for the past three years, have periodically observed and reacted to WPI's process of change. The tenure of this committee extended from 1972 to 1975. A second committee has been constituted for the final stages of the project during 1975-1978.

The reports contained herein are the first WPI-NSF Advisory Committee members' summary assessments of the project based on their evaluation. It is my belief that these constitute a significant resource to persons concerned with the Nation's higher education, in particular science undergraduate education.

Robert F. Watson
Coordinator
Educational Program Restructuring
National Science Foundation

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Dr. John Whinnery

APPENDIX - WPI Project Director's Report to the NSF Advisory Committee for Science Education

Final NSF-WPI Summary Report

of

Dr. Lee Harrisberger

THE UNIVERSITY OF TEXAS OF THE PERMIAN BASIN *Odessa, Texas 79762*

April 24, 1975

MEMORANDUM

TO: Dean William Grogan

FROM: Lee Harrisber Lee

SUBJECT: Final Site Visit Report and Summary Comments.

In each of the site visits we dealt with problems that were explicitly pertinent to the chronology of the development of the PLAN. Thus it was consistent and appropriate that the last visit should be concerned with the final important concerns in the PLAN implementation sequence; the competency, the management and evaluation of projects, and the administrative problems of full operation involving faculty loads, recognition, allocation of resources, and administrative procedures and policies. Progress to date has been remarkable. All previous implementation problems have been dealt with in a way that encourages us all to believe they will be successfully operational. In each instance the problems were solved rather than abandoned. The PLAN remains intact and is operational.

There are three significant areas that were specifically explored in this visit. The following are my observations and comments relative to these final development concerns:

1. Competency Exam Process

As in anything being developed, there is a wide spectrum of variation and success. At our last visit we saw a rigorous effort to assure that students were adequately assessed. The faculty devoted a disproportionate amount of time to the effort and the early Seniors did not find it too oppressive although there was a range of quality of effort. Now that the full load is beginning to hit, the problems of faculty load, uniformity of assessment, and objectives begin to become very real.

The basic problem is devising an assessment that matches the competencies that are to be evaluated - indeed even defining the desired competencies. The Committee on Academic Policy have a proposal that each discipline define some "Behavorial Objectives" that define what is to be measured. Conceptually, I agree, this is the crux of the issue; if you know what you want the student to have, it is much easier to guide him to obtain them and much easier to devise ways of assessing the obtainment.

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I would prefer to define the "behavorial objectives" as terminal skills and attributes that are seen by the faculty and the discipline as needed to succeed after schooling. There should be several; defined in categories of technical skills and basic understandings within the discipline and in general, operational skills such as interpersonal, communicative synthesis, analysis, and judgment.

I strongly favor combining the assessment of the MQP (and perhaps even the IQP) with the competency assessment. It would reduce the load redundancy on the faculty and provide more focus to the process for the student. I also favor Bruce Mazlish's concept of rating a competency (on a scale of 5, etc.) rather than pass-fail. Also such a rating should be done for a profile of attributes defined for the discipline so that the student is never "failed" at the last but truly assessed of his major strengths. Such a profile would be of real value to the student and very useful to his references in recommending for job proficiencies.

A skill or attribute profile rating provides a certain amount of objectivity and organization to the process of assessing competency that would allow several sources of input. If terminal attributes are defined for all to know, then the students themselves can be asked to submit assessment sheets on their teammates, as well as faculty, client supervisors, and consultants.

For quality control I favor the appointment of an annual task force (of faculty and/or outside consultants) to survey the projects and the competency assessment process and report back to the faculty. In addition, each MQP and IQP should be presented orally to an audience of faculty and students and/or client personnel or consultants. The public visibility and critique will provide a natural check and balance to increase quality.

In summary, the competency exam is a basic and necessary feature of the PLAN. It should not be compromised by an erosion to a comprehensive. It should assess - not wipe out or embarass by "failure". The process results should be monitored periodically. A means should be devised to identify those who truly distinguish themselves for honors (this should be done after the assessment process by an honors panel).

2. Project Administration

The progress that has been made to accommodate the volume of this effort has been truly outstanding. The faculty have exceeded the expectations of us all. Having over 1000 students on projects is truly remarkable. The center idea is an excellent administrative vehicle. It has the capability of efficiently sustaining the whole effort in the long haul.

I believe it is imperative that the projects be client-oriented and drawn from outside sources either through the centers or from numerous individual/clients. It is my observation that "real-life" projects are rich in the supplemental benefits so vital to the objectives of the PLAN and are unbeatable for providing enthusiasm and motivation. Equally as important, client problems are unlimited in scope and variety whereas the creative demand on the faculty to provide relevant project ideas far exceeds their ability to sustain - let alone, endure the load. Each discipline should appoint a faculty member as project administrator to work in coordination with the project office to identify clients and client projects for the discipline. I don't see this being a full-time load as it becomes more operational.

A brief comment about the quality of the projects - as would be expected with this volume of activity this early, they vary from very poor to excellent. The poor ones tend to be at the high school science project level involving mostly library research and report writing or routine laboratory testing. The good ones which meet my sense of what the PLAN is about involve a great deal of creative enterprise, search, experimentative analysis, synthesis, and practical applicability - all of which accrue in projects that solve real problems in the field.

Serious consideration should be given to requiring a client to provide a direct cost grant (need not ordinarily exceed $500.00) to support the project activity. Most clients will be glad to assist since they get so much good technical help anyway.

3. Administration and Management

Now that the full operational load of the PLAN has arrived, the necessities of management and support become acutely apparent. Most critical are faculty load, morale, development, and reward. Also vitally important is overall administrative support (direct and indirect) and cost effectiveness. Complex problems don't have simple solutions.

There are several things that came out of our visit that seem to me just might help reduce some of the stress and agony and head things in the right direction.

1. Put more responsibility on the department heads to share in the overall administrative problems, decision making and planning - by having a very close working relationship and communication link with all the decision makers at the executive level. A lot of the faculty concern about administrative decisions comes from misinterpretation and lack of awareness of the forces that are at work. The Heads can do a lot to close the loop if they are fully informed themselves.

2. Put more emphasis on the frequent and informal recognitions of faculty effort - in addition to the major "hero" rewards.

3. Combine competency assessment with project evaluation, stressing outside client-oriented projects. Combining projects with faculty consulting and research would reduce faculty loads and increase their own satisfactions.

4. Seek more project direct-cost grants and allocate inhouse resources to provide more low-cost clerical and technician support.

5. Provide a periodic inservice training program for the new faculty. These faculty come to the WPI PLAN stone-cold and essentially unevangelized. They cannot be expected to "see the light" and become converts and productive advocates without some orientation and discussion of procedures and techniques.

6. Involve the faculty in the development of an evaluation and reward process that will recognize PLAN program activities along with other professional accomplishments. If the reward system criteria mismatches with PLAN activities, other gods will be served than PLAN.

4. Summary Comments

NSF has indeed gotten its monies' worth! This is one of the best administered projects I have seen, and it has met its objectives for the three-year period exceedingly well. Problems of implementation were met and solved with very little compromise of objectives. The PLAN is essentially operational, and the problems that remain can be solved in the same competent manner as all in the past.

Much remains to be done, and continued support by external grants will be necessary to flesh out the program operation and sustain its vitality. NSF should continue to supply additional grants to develop the sustaining mechanisms and enrich the innovative attributes of the program. The university has not yet had an opportunity to institutionalize the program and develop the resources to accommodate its costs and demands. It's like buying a family a pet elephant and not providing assistance for it to provide the ton of hay a day it takes to keep it.

The program is an excellent new instructional system, a commendable addition to engineering education, and a most worthy investment and contribution by NSF. I agree with the other panelists, it is not an exportable package and nothing can be proved that the PLAN could survive nor even get started on another campus. It is a closed system, environmentally dependent, and unique to its own personnel. All of its parts appear elsewhere - all of its concepts and outcomes have prior history. It is unique as a total integrated working system where it is. It proves essentially that a well-conceived plan with good management and generous outside support can be made successfully operational. The Foundation should be encouraged by this to subsidize the implementation of other new programs of instruction for their own uniqueness and effectiveness.

LH/ii

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

DEPARTMENT OF HUMANITIES

Cambridge, Massachusetts 02139

May 7, 1975

To: National Science Foundation

From: Bruce Mazlish, Member of NSF-WPI Advisory Panel

Gentlemen:

Almost all that I would have to say is contained in the various reports, and especially in my Summary Report, to WPI after the visits made by the Panel during the course of the last three years. However, a few additional remarks separately might be in order.

1. On the basis of my experience with the WPI plan, I take a very positive view on the general advisability of conducting a program like WPI-CoSip. It is clear that the NSF support was absolutely vital for WPI undertaking the plan, and that the plan represents a major and successful innovation in scientific and engineering education in this country.

2. As far as the operation of NSF relative to their part in the WPI program, I believe its behavior in allowing the Panel an unimpeded opportunity to judge and evaluate the plan is exemplary. As best I can tell, the NSF support of the WPI administration in implementing the report leaves nothing to be desired.

3. My advice for NSF on how such programs might be managed in the future is in accord with the observations above: behave in the same way as you have with WPI.

I would like now to add some remarks concerning the future relations of NSF and WPI. As strongly as I can, I would like to urge NSF to give continuing and not just start-up support to WPI. It must be clear to all that WPI has limited financial resources of its own. Once the seed money has been given for a plan such as the one now operating, the continuing success of such a plan depends on continuing support, and such support ought to come in part from NSF. While I realize that NSF's general policy is to help institutions begin programs, I think that policy now must be extended to some kinds of continuing support for what otherwise becomes an extremely heavy capital investment by an institution normally short of such funds.

I should also like to comment briefly on the question as to whether or not the plan is exportable to other institutions. In my view, while parts of the plan and its general spirit may be exportable, I do not believe that the plan as a whole can be so transferred (if anyone were foolishly to desire to do so). Though Dr. Cohen of the evaluating team is more sanguine about the exportability of the plan, I think that in my observation spread over three years it is clear that the plan is a process, a living and not a mechanical thing, and depends heavily on the particular constellation of people and events at WPI. For example, the plan could hardly succeed elsewhere without the presence of a key "workhorse" such as Bill Grogan; and Bill Grogans are not found on all campuses. Next, it is clear that an unusual harmony has prevailed among the top administrators at WPI, with George Hazzard, Ray Bolz and Bill Grogan able to work congenially and effectively together. It is not at all certain that this would be the case in most other institutions. Next, the dedication of the WPI faculty has been in my view unusual. Only a faculty strenuously committed to teaching and yet interested in preserving high standards of research and scholarship could pull off the task assigned to them. One could go on listing other factors peculiar to WPI, but it is clear that the surmounting of problem after problem was only possible by a rather unique constellation of key people and efforts; and *that* is not an exportable commodity in the usual sense of an exportable plan. Nevertheless, the plan's emphasis on project work and the way such projects can be carried out can definitely serve as a most useful prototype for other institutions. In that sense, one of the most salient results of the plan *is* in fact exportable.

I should like to conclude by thanking NSF for the opportunity to serve on the WPI Advisory Panel. It has been an exciting educational experience, and one that has taught me a great deal. I only hope that my comments on that experience to WPI have served in some small measure as recompense for what I myself have personally taken away from my service for three years on the Panel.

Sincerely yours,

Bruce Mazlish

Bruce Mazlish
Professor of History
Head of Humanities Department

BM/ar

To: William R. Grogan, Dean of Undergraduate Studies
From: Bruce Mazlish
Re: Summary Report Based on the Final Panel Meeting (April 17, 1975)

In this final report, I shall attempt to take the long view, looking over our six visits to WPI in the course of the last three years as a total educational experience. While concentrating on various findings experienced at this last meeting, I shall be bearing in mind the changes over time to which each item that I discuss has been exposed. You now have your first real graduating class, so to speak, under the Plan. I must confess that I feel like a WPI graduate myself, as a result of following the Plan for the last three years. It has been an exciting educational experiment to watch, and I am amazed to discover that, after all of the difficulties made obvious to us during the twice yearly visits, you have even survived. Right at the beginning, however, I want to sum up by saying that you have not only survived but flourished. With that encomium, let me now turn to more specific comments.

Requirements

It is clear that at the heart of the requirements lie the projects, both the MQP and the IQP. While the courses are important -- some students felt that their importance was not sufficiently underlined for the students -- it is obvious that what counts is the preparation they afford for satisfying the general requirements at WPI. The projects, along with the competency examination and the sufficiency, are where the Plan really gets its test. Based on all my visits, there is no question but what the projects are generally approved by both students and faculty. The students see the MQP as a help in getting a job, and indeed are spreading the word that the choice of a difficult MQP is desirable in that regard. IQP's have a fallout that go well beyond the specific project undertaken. They seem really to bring the student out of any shell he or she may be in, open new vistas, and achieve their purpose of making the students more socially aware. The success of the IQP does seem to depend heavily on the individual faculty member involved, and it is clear that those faculty members who participated in the Sloan Summer Study were and are most helpful to their students. For both MQP's and IQP's, the results were better when the projects were generated in connection with an outside agency (such as St. Vincent's Hospital) rather than being the eccentric interest of a WPI faculty member. There is, in fact, a bit of a paradox in that the students and faculty appear to approve of the projects almost without reservation, whereas my own experience in talking with some of the students and faculty about specific projects led me to conclude that the projects were in some cases trivial and misguided. Therefore, it seems to me imperative that some sort of control mechanism be set up. A small committee of three or four persons, operating more or less the way our NSF Panel did on this last visit, could sample a number of the projects and report on them. The singling out of some projects as good and bad models would, I am sure, have a large scale persuasive effect on the future projects. This sampling could probably best be done by outsiders, and it would be entirely legitimate to ask for NSF funding for it. It might also be useful to make defense of the individual projects public. This would have the advantage of serving both as a control mechanism and of further rewarding the student and faculty participants by giving some sort of public recognition and critique to their efforts. Lastly, the Washington projects seem to be one of the most exciting possibilities in the Plan, and it is critical that people be encouraged to go, both staff and student, and that sufficient advance registration for this purpose be undertaken. As I understand it, there was a problem in timing in securing the last batch of students, with sign-up required before those who had returned from Washington had a chance to spread the good news. This, however, seems a mechanical matter that can readily be attended to, and the Washington part of the Plan should become increasingly successful.

What is astounding in relation to the projects is the way in which the faculty has carried the burden. Throughout the three years, there was a very real question as to whether, as the Plan went into steady state, the load on the faculty would become unbearable. To my astonishment, the faculty appears able to grapple with this load, and indeed in many cases apparently to enjoy and derive inspiration from it. I can only register my amazement, and deal with the possible problem involved in it somewhat later.

Sufficiency

There seems to be no problem with the sufficiency, although the question of allowing social science to satisfy the requirement still lies ahead. This is true even though the social science group at this moment does not wish to be included as part of the sufficiency. In general, the students perceive the humanities faculty as being good in quality and offering a sufficient range of subjects. The few students who might be considered "majors" in areas related to the humanities faculty do feel somewhat isolated and peripheral, but this is a problem at all science and engineering schools, and there is only very little that can be done about it. Perhaps the humanities faculty can be encouraged somehow or other to establish a society which involves such people, and to offer certain kinds of events which directly point at them.

Intercession

As we have been informed, the intercession program has apparently stabilized at around 55% level of student participation. Students and faculty appear to be positive about the intercession, and I get the impression that one of its main functions is to help in creating a sense of community; for example, students now stay on campus during the intercession period rather than leaving for their homes. In reference to a sense of community, however, I was particularly struck by the fact that in talking with the graduating students about their four year experience, there was little or no mention of the extracurricular activities or environment at WPI. Each student simply gave a recital of his or her achievements, in the sense of reeling off the steps and requirements by which he or she had reached the stage of graduation. It did seem a slightly mechanistic attitude, leaving out of account the larger formative influence that one might have expected to figure in their overview of their education at WPI. In the light of this fact, the community enhancing aspect of intercession is especially valuable.

Competency Exam

Here, clearly, there is still a major problem. It is not, as I at first expected, a problem of an overload on the faculty. Once again, they seem to be carrying the load without undue verbalization of discontent. Discontent, however, is strong among the students. They do feel that it is unfair to be sandbagged with the competency examination at the end of their stay at WPI and to run the risk of failing. They also believe that it is not clear what the competency exam is measuring, that different departments offer vastly different examinations, and grade them according to very different criteria, and that too often the examination is measuring comprehension rather than competency, i.e., that it is centering on final results rather than on process of learning. These are all serious charges and need to be dealt with carefully.

As for the faculty, although they seem not to complain of the burden of the competency exam, it is also clear that it is becoming the focal point of a possible counterrevolution. This, in fact, may be subtly tied up with the whole question of certification as well. If the competency exam can be turned into a measure of the student's professional comprehension of a particular field, it begins to subvert the general intention of the Plan. Students will learn very quickly that they must take specific courses in order to pass.

To deal with the problem, both as seen by the students and the faculty, I reiterate my suggestion that the competency examination be graded on a 1-5 or similar scale, and that no student who has reached that point in his work at WPI should be said to be totally incompetent. Next, as Lee Harrisberger and I both felt strongly, competency should not be an all or nothing thing, but should be measured on five or six items, for example, mastery of general principles, articulateness, ability to innovate, etc., and the student could be given a 1-5 rating on all of these items. In addition, it would seem very important to have an oversight committee. As with the projects, one would want a small committee, which would look over the various competency examinations given by the different departments and seek to hold them to certain general criteria agreed upon ahead of time. Such policing (there is a similar distribution committee to oversee the MIT requirement in humanities, social science and art) would operate more in terms of persuasion than in terms of flat yes and no.

All in all, it seems that, with the exception of the competency examination, the various parts of the Plan requirement are acceptable and in working order. The competency examination will need further close attention. One has to grapple with the problem of generating new and adequate competency examinations constantly -- and perhaps some standardization and repetition of these examinations would be in order in different subjects -- and making sure that they adhere rigorously to the spirit of the Plan. Having come so far, there is no reason to assume that WPI will not be able to cope with this problem as it has with all the other problems over the three years of our visits.

Seven Week Term

On our first few visits, the issue of the seven week courses was both visible and excitable. What becomes clear now, however, is that it has passed as an issue and that indeed it is not critical to the Plan. Thus, although three-quarters of the faculty seem to have doubts about the seven week courses, it is accepted as part of the Plan and there seems little point in making it an issue again. It has, in fact, served its original purpose of shaking up the faculty and allowing for off campus project needs, etc. Thus, all that seems required is flexibility, such as allowing the mathematics department to offer fourteen week courses either directly or covertly.

Other Topics

The admissions procedure seems to be working well in relation to the Plan. It is not so much that WPI has been able to attract additional numbers of students (though without the Plan there might have been a drop), but rather that the right kind of student is being attracted now by the Plan. Indeed, most of the present freshman class has come because of the Plan, and they seem a very articulate and broadminded group in comparison with earlier entering classes. Certainly, they become more articulate as they pass through the WPI Plan.

The evaluations by Drs. Cohen, Baker and Gabarro have been hopeful in monitoring the development of the Plan through the three years. They have often given objective validation of subjective impressions held by the Panel, for example. The use of the control schools now allows WPI to measure its total achievement at the end of the three years against what can be seen as a steady check. The control school evaluation, incidentally, may also serve to help NSF in its deliberations on the question of whether the Plan is exportable or not.

Advisers are obviously an important part of any college experience. Some WPI students see the advisers as critical to their success under the Plan, but others do not. While all agree that one has to start planning early, it is not agreed that this can only be done with the advice of a helpful faculty member. In my own view, the situation is no different from that at any other college or university. Advisers will vary greatly in quality, and the students equally so in their need to have advisers with whom they do or do not work closely. In any case, it is clear that the good advisers at WPI are, as might be expected, swamped. Again, while this is an important problem, I do not see it as a critical one.

The consortium is obviously a "good thing," but it does not seem very meaningful at WPI. At best it is a very peripheral affair, allowing the unusual student to take advantage of some particular need. It seems, however, to be a fact of life that the overwhelming number of students at WPI simply cannot take advantage of the consortium as a meaningful part of the Plan experience.

Faculty

As one student remarked, you can change the students in the course of four years but you can't change the faculty in that time. It is remarkable, nevertheless, how much the faculty has changed in the course of our three year visits, in the sense of rising to the challenge of the Plan. I have been impressed by the dedication of many long-time members of the WPI faculty to the Plan and to the way in which new faculty, for example in life science or social science, are fostering the aims of the Plan. To my amazement, as I have said earlier, the earlier dire predictions of faculty breaking under an overload have not been realized. There is still, of course, the question of rewards, and what I called in my last report a delayed shock reaction ahead. There is little point in repeating our repeated warnings here. While many members of the faculty have obviously, and rightly so, gotten much gratification out of the Plan making WPI nationally known and their being singled out for attention, more tangible rewards must be provided to them. This is especially true of the pro-Plan people, those faculty who were the early stalwarts and now feel that they are being overlooked or slighted by the administration, or else that others who have not been pro-Plan are being given equal or greater rewards. Some of this can be dealt with, I believe, by more strongly emphasizing to department heads, who must be very carefully selected, that it is their duty to provide fairly constant verbal reward as well as other kinds to the faculty distinguishing themselves in the service of the Plan. It is also imperative that the top administration make personal efforts to convince the pro-Plan faculty that they, the administrators, are still resolute in their support of the Plan. In this case, it is not enough to be favorable to the Plan; one must also be seen, to be perceived, as favorable.

It might be well in the context of my comments on the faculty to say a word about graduate programs. Most of my colleagues on the Panel feel that the graduate effort is generally a diversion of resources from the Plan. I am less fully persuaded on this point, and believe that graduate developments provide a needed level of research activity for the morale of many key members of the WPI faculty as well as providing an intellectual strength for the Plan itself on the undergraduate level. Still, it is clear that this problem cannot be swept under the rug, but must be constantly checked and looked at by the administration.

Administration

Though the faculty -- as faculties probably always do -- sees the administration as padded and over-costly, it is clear that the administration is stretched terribly thin. While we have all been worrying about the overload on the faculty, a real problem of course, we have slighted the fact that the administration is really also very overloaded. Bill Grogan's accomplishments and work load are simply overwhelming. The President and the Vice President, George Hazzard and Ray Bolz, have extremely heavy obligations which they have carried out splendidly, with seeming unperturbable calm and great responsibility. But these are only three men, carrying the top administrative load of a major innovation at WPI. To help relieve this load, something along the lines of David Riesman's suggestion about internees to the President should be pursued. While recognizing the budgetary pressures ~~on WPI,~~ it still seems necessary to flag a problem that tends to be overlooked in our concentration on the salient problems related to students and faculty.

Summary

How can I sum up except to say that a Plan that seemed impossible of implementation three years ago is now moving along briskly and well. If one had known ahead of time the problems to be encountered, one would have wisely declined to begin the Plan at all. Yet, faith seems to have overcome or dealt with almost all of the problems. On visit after visit, we were confronted with major problem areas whose solution seemed critical to the Plan and yet extremely dubious. On our next visit, however, we would be amazed to discover that either the problem had been overcome by direct action or had simply been transcended by the emergence of new problems. Nevertheless, the result was not a house built on cards; as each part of the Plan became increasingly operational it provided a solution rather than a dismissal of the problems we had encountered earlier. It is a tribute to the extraordinary tenacity of all involved, especially the faculty and the administration, that they did not give up hope, but instead went to work and dealt with the problems as they arose. This is not to say that all of the difficulties with the Plan are over once and for all. The competency examination still looms as a major obstacle to success. The fall-off of enthusiasm by pro-Plan proponents is potentially very dangerous. A lapse into complacency, or worse, the emergence of a counterrevolution cannot be entirely discounted. Yet, with all this said and acknowledged, I must conclude that the WPI Plan is an exciting and successful innovation that bodes well to become a prototype of future developments in scientific and engineering education. From my point of view, over these last three years I have had a truly remarkable experience and received a most stimulating education.

Final NSF-WPI Summary Report

of

Dr. George Pake

THE WPI PLAN: NSF ADVISORY PANELIST FINAL REPORT

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I. INTRODUCTION

The NSF-WPI Advisory Panel has met six times since the fall of 1972. A typical meeting comprised two days of both structured and unstructured sessions with students, faculty, and administrators, as well as executive sessions of the Panel. Panelists were given access to any data or individuals they asked to see; all of WPI became an open book which we were free to peruse or study in depth as we wished. The Panel involvement extended to attendance of faculty meetings, meeting with such committees as the faculty committee on tenure, visiting with professors in their homes, lunching with students, and one-on-one interviews with student, faculty, and administration personnel. A few panelists made additional visits on their own to talk with faculty and students, to attend classes, etc. It is quite possible that some academic members of the Panel have a better overview of WPI than they do of their home institutions.

Many great accomplishments would never have been embarked upon if their architects and implementers had known in advance the difficulties or known the credentials of those who believed the task to be unachievable. The WPI Plan and the efforts of WPI to date in carrying the Plan forward seem to me to fall into just this category of accomplishment.

When the Panel met during the first year it foresaw a host of problems; few if any of the Panel Members believed WPI could surmount these problems and that the Plan would be as successfully intact as it is today. Our foresight with respect to the nature of the problems was, I believe, quite good. What we - or at least I - failed to foresee accurately was the determination, perseverance, and resourcefulness that the entire WPI community has brought to bear on those problems.

Significant problems remain and the Plan's future is not assured. But the quality, enthusiasm, and acquired maturity of the first graduates who have spent their entire undergraduate years under the Plan testify to a success that none of the NSF-WPI Advisory Panel would, I believe, have predicted in the fall of 1972.

II. OBSERVATIONS ON SIXTH PANEL VISIT

For the first time, the Panel could interview graduating seniors who had been under the Plan since their freshman year. Interviewing these students was, for me, the high point of the six visits. They were articulate, pleasantly self-confident, and they exuded enthusiasm for the Plan and immense satisfaction with their WPI experience. They have a sense of accomplishment, a sense of some ability to function professionally in real-world circumstances, and a desire to move ahead.

These Plan graduates are not without criticism of the Plan and their experiences with it. But they understand that experiencing the bugs in the Plan goes with the privilege of being its first products. These graduates, most of whom came from middle class homes and many of whom are first-generation college graduates in their families, are to me the most effective salesmen (salespersons if you must!) of the Plan.

Their experience with the projects seemed to be much appreciated and highly valued, whether or not the project quality was judged later on by panelists to be high - a topic about which I will shortly say more. I have a strong subjective feeling that the IPI (Individually Prescribed Instruction), MQP (Major Qualifying Project), and IQP (Interactive Qualifying Project) experiences, along with the clearly traumatic Competency Exam, combine to breed a bachelor's degree graduate more articulate, poised, and on the whole self-confident than would a traditional passive undergraduate experience of required classroom courses.

The Competency Exam remains a problem, though it is less debilitating to the students than when the first round of these exams hit the students.

The new problem in this visit is the Qualifying Projects. Concern about them has shifted, in my mind, away from the question of whether the faculty can manage the load of such projects to whether, while managing the quantity of projects, adequate quality can be established and maintained.

There are some undercurrents of faculty discontent with the administration. This is disquieting to me in that both faculty and administration have labored effectively under heavy overloads, and I wish each group would fully appreciate the accomplishment of the other. In many respects they have both "played over their heads". But such heavy overloads develop a weariness that more readily admits doubt of the partner group's output or effectiveness. All told, considering today's endemic strain on private higher education, considering the thinness of WPI administrative staff in relation to the needs of the Plan, and considering the heavy load carried by the key faculty members who make the Plan a reality, I judge faculty-administration relations to be good-to-excellent. Professor Riesman reminds us that these days all faculties are paranoid; I am saying that WPI's is much less so than anyone would predict who knows the workload, the disorientingly high recent rate of change, and the WPI financial resources available for salaries.

On balance, the Plan has I believe provided higher faculty morale at WPI than we would find there if the traditional program had prevailed. And the WPI senior level administration (Hazzard, Bolz, Grogan) is of a caliber WPI could not have aspired to without the Plan.

The sixth Panel visit has shown that WPI can deliver a superior undergraduate as a product of the Plan while to date surviving institutionally some very severe stresses.

III. 1975 EVALUATION OF THE WPI PLAN

The following represents my overview and conclusion after observing the phasing in of the WPI Plan over the period of the six Panel visits.

Individually Prescribed Instruction

IPI works, but it works better in some subjects than others, and some students are not mature enough nor self-motivating enough to do it well. I am sympathetic with the problems that mathematics faculty feel they have with IPI and the 7-week term, particularly at the lower undergraduate levels. Use of more conventional mathematics courses and the double 7-week term (in effect a 14-week semester) seems to me appropriate, if the Math faculty prefers to do so. I do not regard this as an erosion of the plan, which is after all aimed principally at the engineering specialties and the natural sciences.

The Seven-Week Term

This loomed as the big problem during our first two visits. In spite of some obvious disadvantages (e.g., a one-week student illness is a 15% loss of time from the instructional module, whereas it would be a 10% or 7% within the conventional quarter or semester calendar), I believe it has been helpful in forcing re-examination and rethinking of the instructional and project offerings.

If a change were now to be contemplated, I believe that the 14 week semester would be less disruptive of the Plan than a change to 10 weeks, which is, so to speak, neither fish nor fowl in relation to the experience of the last four or five years. The 7-week term may have been essential to launching the Plan; I believe that either the 7 or 14 week term can accommodate the basic philosophy and essential elements of the Plan.

The Qualifying Projects

These projects have the great benefits for the students that I mentioned in Section II - development of initiative, confidence, ability to work with others. But some project problems have substance and potential, whereas others lack one or both. Faculty advising and monitoring is critically important here, and quality controls within and among departments are desirable, but difficult to achieve without further burdening the faculty, e.g., in review-boards.

A small external review board might be very helpful in checking samples of projects for quality, and in feeding back to the departments and the administration.

It appears that at least two external project centers, the Washington Center and the St. Vincents Hospital Center, have provided real-world problems of substance and quality; perhaps the gradual development of more project centers is a direction in which to move. The newly planned joint graduate venture with the Worcester Foundation for Experimental Biology offers promise of good IQP's and MQP's related to regular research and graduate degree research being pursued at the Worcester Foundation.

The Sufficiency Requirement

The humanities faculty and program has grown in strength during the phasing in of the Plan: the Plan's Sufficiency Requirement has helped the faculty as well as the students. There was one student who expressed to me a concern that his Sufficiency program constrained him artificially from pursuing social science aspects of his humanities study. This constraint, I believe, need not exist. In any event, nothing (except workload) should preclude such a student from seeking counsel with faculty social scientists as he works out his Sufficiency.

The Competency Exam

I believe this is the element of the Plan in most need of attention. The students feel that the criteria among the departments are uncertain and uneven, that the number of first-time failures is inconsistent with measured academic performance during the previous 3 or 3 1/2 years, and that, when the exam is failed and therefore must be repeated, the timing of the event is psychologically about the worst that could be found. I think all of these student views are largely correct.

Furthermore, the Competency exam and its significant number of repeats places an almost intolerable final layer of workload on a faculty heavily burdened with advising, instruction, and project guidance.

Throughout the Competency issue runs the conflict between a faculty desire to test for comprehensiveness of background in the major field and a desire to measure competence in solution of a particular problem. In either case, but especially in the comprehensive version, the faculty is pressed to come up with new and different measures as student files fill up with exam questions. My choice in this dilemma is outlined in Recommendations to WPI, Section IV below.

Summary View of the Plan

For the student capable of developing initiative and even semi-serious about deriving benefits from their WPI experience, the WPI Plan produces a superior product. There is a group of WPI students (and doubtless always will be) who do not meet those conditions: one cannot yet conclude either the effect of this group on the environment of those students profitably engaged in the Plan, nor the effect of WPI on those students not well suited to the Plan. Are they any worse off at WPI than they would be in a traditional program? My guess is not.

The Plan's continuing success hinges critically on faculty conscientiousness, effectiveness, and stamina in advising, project identification and monitoring -- as well as the usual faculty duties of instruction and a larger than usual amount of committee work.

The net conclusion of the foregoing paragraphs is that the WPI Plan produces a superior product at a higher academic cost. My subjective judgment is that the product increment proportionately exceeds the academic cost increment, i.e., the game is definitely worth the candle!

This leads to the ultimate question: as WPI settles down to this effective experiential learning program, can resources be found to relieve the faculty overload and sustain the program? In the very long run the hope may have to rest on industrial support, presuming that industry will recognize that it hires a more useful and effective graduate when he comes from WPI. This challenge is squarely before the administration, because the fickleness of public and private foundations with respect to support of solid programs once their "innovative" lustre wears off is known to every leader in higher education (and secretly by nearly every foundation executive). See my further barbs on this topic in Section VI.

My conclusion after three years during which I have seen the first class of graduates who have been fully under the WPI Plan: It is the most successful experiment in educational reform with which I am familiar.

V. RECOMMENDATIONS TO WPI

Proposed Linking of Competency to the MQP

I believe that the two major difficulties the students have with the Competency Exam would be solved by tieing it to the Major Qualifying Project. The first difficulty to be eased is that, by defining the MQP as the domain within which the student is to be examined, his competence with respect to that domain is much less likely to be confused with comprehensive knowledge of a broad field.

The second difficulty is the psychologically awkward event (evidently occurring with some frequency) of failed and repeated competency exams following the student's successfully having met all previous Plan objectives up to the middle of the senior year. Competency based on the MQP would confine the exam to topics that (a) the student has studied in some depth and can reasonably be expected to have mastered, and (b) the student will regard as an appropriate culmination of his MQP effort rather than an irrelevant general examination. (This would be analogous to defense of the thesis at the completion of a graduate degree program. Instead the Competency Exam is now analogous to asking that a Ph.D. candidate, after satisfying course requirements and having his thesis accepted, take a comprehensive exam in his discipline. If he is judged by the faculty to have flunked, requiring a repeat exam, it is readily understood that he will view the whole procedure as nonsensical and even unfair.)

Another virtue of this proposal is that it should ease the load on the faculty. The MQP adviser can plan the Competency exam as an outgrowth of his involvement with project guidance, which should be easier than working up new general competency questions. Also, I assume that the students will have a higher initial passing rate on an exam related to the project material in which they have been so deeply immersed, thus consuming less faculty time in re-examination.

A second possible benefit would be improved quality control on the projects. If the MQP faculty adviser knows that a second faculty member will join him in the Competency exam following the project, there will be subtle influence to keep the quality high.

General Recommendations

The WPI Plan and the progress made with it to date is the most exciting and productive educational innovation or reform I have encountered. In spite of the many problems, some solved and some remaining, the accomplishments by WPI faculty and students in developing and implementing the Plan represent tremendous achievement.

My recommendation is clearly stick with the Plan, don't lost heart in the face of some inevitable problems and a likely period of doubt as some of the lustre wears off. In short, keep up the good work!

VI. RECOMMENDATIONS TO NSF

General Advisability of WPI-CoSIP Type Programs

I am extremely enthusiastic about the WPI Plan and the indispensable impetus given to it by NSF CoSIP support. NSF is certainly to be commended for recognizing that the proposed WPI Plan had substance growing from a genuine ground swell within the WPI faculty. In my own experience, such proposals for innovations in education typically are either the hastily considered efforts of a few who cannot really carry their faculty colleagues with them in sustained serious effort, or they are relatively conventional programs dressed up to appear innovative in order to seek funding. Foundations, both public and private, let themselves in for the latter by being too much caught up in 'innovation', I believe. Improvement of the undergraduate learning experience is the goal. Most innovations are unlikely to be improvements, and only rarely does a sound innovation such as the WPI Plan come along. That NSF recognized the potential in the WPI proposal is very much to NSF credit.

I conclude that a CoSIP or RULE (Restructuring of Undergraduate Learning Experience) program in NSF is highly desirable, but only under certain caveats and with realistic expectations: very few proposals for such restructuring will have all the ingredients that have contributed to the WPI Plan's success to date. Those ingredients are:

1. A strong nucleus of faculty leadership inspired to improve undergraduate education.
2. Sound planning.
3. A faculty willing to take on heavy loads to support the effort.
4. An extremely able and well-organized Dean of Undergraduate Instruction to provide administrative organization and initiatives.
5. A university administration committed to the effort, able to comprehend it, and effective in "selling" it to alumni and external agencies.
6. A strong, independent, respected external Advisory Panel.

I believe I can list the sixth requirement in the WPI Plan without being immodest, since the quality of my Panel colleagues will fully make the case, totally neglecting my presence. Such a panel provides independent assessment, can take an overview without being consumed in detail, can provide welcome encouragement in response to progress made, and can offer constructive criticism and suggestions. The hardworking, overloaded practitioners of such an educational restructuring draw an important reward, I believe, from the dedicated constructive interest of educators and scholars of the caliber of Messrs. Harrisberger, Mazlish, Picha, Reed, Riesman, and Whinnery. The free hand given to the Panel has been a most enlightened NSF policy - indeed it may be essential to recruiting and retaining panelists such as those listed above.

The future counterparts of WPI-like improvements in undergraduate education must be discovered and given the opportunity to be tested. DO NOT EXPECT TO FIND MANY.

What is exportable from the WPI Experiment?

I am tempted to say that only the list of six required ingredients is exportable. That is possibly too "flip" an answer, yet I am reluctant to claim more.

Presumably the projects, whether MQP or IQP, could be exported into circumstances where the curriculum is otherwise relatively conventional. But I believe that the Individually Prescribed Instruction, the shorter and more intensive seven-week term, and other elements of the WPI Plan develop a degree of student self-reliance that contributes significantly to the success of the MQP's and IQP's at WPI.

Innovating versus Sustaining

During my 22 years in academic life, prior to departing for industry, and also during my past five years as a trustee of a private foundation, I have developed a strong aversion to the innovation syndrome of supporting agencies. Everyone likes to be credited with having or helping to launch a new idea. Far fewer have the resolve or perseverance to sustain solid new ideas through their less glamorous periods of middle-aged steady productivity. I have in the past accused the private foundation world of happily depositing babies of innovation on the doorsteps of private colleges and universities, leaving those institutions with the hapless financial task of nurturing the innovations through childhood and strapping ever-hungry adolescence toward solid maturity.

With the foregoing observation (prejudice) clearly expressed, I urge the National Science Foundation to recognize what I believe to be a fact: a dollar spent sustaining the (to date) highly promising WPI Plan will provide more educational return than a dollar gambled on "wild-catting" for further viable educational reform.

Now, since the successful WPI Plan experiment could not have been performed without such speculative investment, I am obviously not opposed to wild-catting. What I am saying is that it is pointless to invest in the search for new resources without following through with support for their steady production. This calls for a balance between sustaining and innovating funding that few foundations, public or private, have seemed to me to be willing to strike!

George E. Pake
May 1, 1975

Final NSF-WPI Summary Report

of

Dr. Kenneth Picha

REPORT TO THE NATIONAL SCIENCE FOUNDATION

ON THE PROGRESS OF THE WPI PLAN

K. G. Picha, Advisory Committee Member

The Faculty and Administration of WPI are to be commended for the excellent progress in implementing the innovative WPI Plan for engineering education. Many of us were extremely skeptical over the past three years as to whether or not WPI could indeed implement the Plan. The Plan has been implemented, all freshmen are now on the Plan, and a sizeable number of seniors are graduating. Graduates of WPI are being placed in good industrial posts and are being accepted at prestige professional Graduate Schools. Much of the success to date is due to the keen perceptions of problems and excellent approaches to problem solving of Dean William Grogran. NSF should continue its support of the WPI Plan for at least another two years since a great deal of good experience and data are being developed that will be of value to other engineering schools and, I suspect, to Specialized Accrediting Agencies.

It is understood that NSF has interest in determining what components of the Plan might be useful to other institutions. It was agreed by the Advisory Committee that WPI was a rather unique place five years ago in that it faced a rather uncertain future unless some dramatic changes took place. There existed some key faculty members who envisioned the Plan and were ready to work extremely hard to make the Plan work. There were also a unique set of talents and interests which made the IQP's and the MQP's possible. The conclusion one reaches is that it is unlikely that the same set of circumstances will exist at another institution such that the Plan can be exported.

It is likely, however, that the concept of working on real problems, both technical and social, can be exported. Indeed, from my own perspective and experience real problem solving and senior theses seem to be returning to many engineering schools. It is hoped that industry and government agencies will recognize the educational value of working with our Nation's engineering schools and will be willing to make the manpower investments as well as financial investments to continue to encourage these efforts.

Specific problem areas observed during April 1975 will be commented on in a direct report to Dean Grogan. The most significant difficulty which I perceive as being unsolved and perhaps irreconcilable in the future shall be discussed in this report.

The faculty members who conceived the Plan recognized that the implementation of the Plan would require every faculty member to become almost a zealous missionary devoting all their energies and talents to the Plan. The Faculty Reward structure had to be changed to give adequate rewards for superlative performance in Plan activities. Clearly this meant that the traditional rewards for scholarship-research and publications had to be deemphasized for several years.

I expressed considerable skepticism three years ago regarding changes in faculty reward structures. The conflicts of trying to maintain viable doctoral programs and implementation of the Plan were obvious. It was my judgment that substantially all of the faculty effort had to be devoted to the Plan and that perhaps it would be wise to drop doctoral education at WPI.

Unfortunately the conflict remains and in my judgment the success of implementing the Plan is in serious jeopardy because progress has not been achieved on solving this problem. It is understood that a major change in thinking is being called for. On the other hand, the conflict appears to be a major stumbling block in most innovative undergraduate engineering programs I have studied.

The argument can be made that faculty members can only stay abreast and indeed ahead of technological change by doing doctoral level research. I too have used that argument for many years in making key personnel decisions. I am now persuaded that other ways exist for maintaining faculty professional growth. It can be argued that faculty members working on real industrial and government problems with very bright seniors and masters students can stay alive intellectually and grow professionally. In fact, one of the attractive features of the WPI experiment was a test of this argument. Dean Gordon Brown of MIT used to say that industry was the storehouse for technology and the University the storehouse for science. Accepting his concept leads one to believe that an engineering school can stay at the forefront of technological change by day to day interactions with a variety of industries over a period of five to ten years.

Should the Faculty and Administration at WPI decide to really bite the bullet and focus all their attention to the Plan, some major questions evolve as to faculty mobility in the face of increasing tenure percentages (a problem we all have). My guess is that as more engineering schools adopt the problem solving mode of engineering education, that faculty members at WPI will be approached with possible positions. On the other hand, it might be that WPI might begin to lose its valuable faculty members to industry. (Industrial starting salaries for BS students are once again equal to Assistant Professor's salaries.) There could emerge a flow of people between WPI and industry which might be one of the best things that could happen to engineering education.

The problem I describe is an easy one to discuss, but an extremely difficult one to solve since it raises the crucial issues of today's academic world. WPI demonstrated it could depart from the traditional concepts when it adopted the Plan. Hopefully that same spirit of experimentation and innovation will come forth to solve this problem as well.

Final NSF-WPI Summary Report

of

Dr. Eugene Reed

May 1975

The WPI PLAN: Assessment and Recommendations

E. D. Reed

The WPI Plan is a daring attempt of an old established and prestigious engineering school to change itself. The roots of this change are twofold: institutional survival and a perceived need for a new kind of engineering education.

Located in a region of the country rich in institutions of higher learning, WPI, some years ago, faced a bleak future. Engineering enrollments, nationally, were sagging while expenses and hence tuition were climbing sharply. As a private and not heavily endowed college, WPI foresaw difficulties in competing with nearby public institutions which offered quality programs at a fraction of the cost. There was need, the faculty sensed, to differentiate WPI's educational offering.

The other root of WPI's Plan was a strong conviction of the faculty that today's engineering education needed radical change to respond better to the needs of modern society. The modern engineer, according to the Plan, should enter his profession prepared for industrial problem-solving and should understand the impact of his technical output on society. He should be well grounded in the humanities and should have the opportunity in school to exercise initiative, to make plans and decisions, and live with the consequences.

These ambitious features of the Plan were to be offered not just to a small minority of entering students of outstanding ability but made the standard program for all.

The revamping of WPI's program from its traditional format to the Plan was an undertaking of immense difficulty and complexity. It was tackled by the faculty with extraordinary dedication and ingenuity and received the unreserved backing of the administration. With the graduation this spring of the first generation of Plan students, an important milestone has been reached and the results of WPI's institutional transformation are beginning to emerge.

We met with six seniors selected at random by Dean Grogan. They were an impressive group: articulate, self-confident, mature, knowledgeable in their field, and wholly sold on the Plan. They would choose the Plan again and recommend it to friends and relatives. This group of young men and women are a credit to WPI. They will go out into the world, including top graduate schools, as living advertisements of the Plan.

The Plan therefore is off to a fine start with many of its indicators looking favorable at this early stage. But there are problems. In my own view: one major problem and a series of minor problems. If WPI is able to tackle the major one, the rest will take care of themselves--in time.

The major problem is cost. The Plan represents education inherently more expensive than the traditional format. I don't know how much more expensive--my estimate: 30% to 50%--nor do I know how WPI will pay for it. The excess cost stems directly from the Plan's need for substantially more faculty per student.

The early success of the program has been made possible by a burst of faculty dedication and effort which cannot be sustained for the long haul. It is essential therefore that this problem be understood and faced.

In the following I will deal first with faculty overload and then take up some of the lesser problems.

FACULTY OVERLOAD

WPI embarked on the Plan with an already lean faculty: a student-faculty ratio of 14. Every essential feature of the Plan has added to the faculty load; none has reduced it. Compared to a traditional situation:

The WPI student needs more advising and monitoring to steer him through his custom-tailored study plan.

Several hundred projects must be kept going at any one time and their quality maintained at a high level since much of the student's education derives from projects.

Hundreds of competency exams must be designed and implemented yearly, each tailored to an individual's plan of study.

New incoming faculty requires more time to become fully productive, again adding to the burden of the incumbent faculty.

And yet, with all these additional demands on the faculty imposed by the Plan, the student-faculty ratio has stayed unchanged at 14. Contrast this with Harvey Mudd, an engineering school offering a similar program, which operates with a student-faculty ratio of 9.

So why is the Plan working so well at this stage? Certainly, the first graduating students have impressed us as competent, articulate and solidly behind the Plan. The answer lies in the faculty's willingness to put in extraordinary effort, dedication, and long hours way beyond the call of duty. The Plan, after all, is the faculty's very own creation and the majority are strongly motivated to see it succeed.

But what about the long haul? Can this outpouring of faculty energy and motivation, triggered by the excitment of radical, self-generated change, be sustained indefinitely? I think not. I have come across professors putting in 12 or more hours a day plus weekends over long stretches of time and yet barely keeping up with nonpostponable duties. There is lack of time for upgrading courses, lack of time for just thinking. There is talk of the need to exercise selective neglect. There is reduced opportunity for consulting because of the time demands of the Plan, aggravated by a salary structure which lags behind comparable institutions. It all adds up to a serious problem that must be understood and met.

The work load clearly is not uniform across the faculty. It ranges from severe overload to underutilization. Considering, however, normal spreads in talent, motivation, vitality, and productivity, the work load will never be uniform, but some redistribution would help and may indeed be feasible.

What I believe is needed is a thorough systems study to determine the dimensions of this problem: how much faculty time is needed to implement the Plan at a high quality level and how much faculty time is in fact available. Such a study should concern itself with the steady-state rather than the present transition phase since I'm confident that momentum will carry the Plan through the remainder of its developmental phase. If such a study shows a modest faculty deficit, say of 20%, we may expect to close the gap through minor changes and economies without jeopardizing essential features or quality. If the study, however, discloses a much greater deficit in faculty time, then we are surely headed for trouble, and more drastic remedies will be needed.

In summary, I see faculty overload as the overriding problem of the Plan. Other problems, such as advising, projects, competency exams, 7-week term, all stemming from the newness of the Plan, can be corrected given the availability of adequate faculty time. In the absence of understanding the problem of faculty load and dealing with it, the Plan will be faced with a continuum of problems--different ones at different times--all symptoms of a common root cause: faculty overload.

OTHER FACULTY RELATED PROBLEMS

1. The faculty feels that neither department heads nor administration are aware of individual work loads. To be sure, computer printouts of work assignments exist but little use is made of them to give either recognition or relief to overloaded faculty members. This is a task which department heads should address.
2. Some faculty members feel underrecognized. They put in extraordinary effort, yet seldom hear a word of praise or recognition. Initiatives are therefore needed by department heads and members of administration to show recognition and to improve communications with individual faculty members.
3. The faculty considers itself underpaid and losing ground with respect to cost of living. They question the fiscal decisions of the administration and lack confidence in the Committee on Financial and Administrative Policy charged with understanding, influencing, and explaining fiscal matters. I believe WPI has valid answers to these faculty concerns, but the facts must be disseminated. I recommend that the Committee on Financial and Administrative Policy be revitalized and charged with establishing better rapport and communications with the faculty.

4. The reward system at WPI is guided by the Committee on Tenure and Promotions. We found the members of this committee of high caliber and their organization and procedures admirable. Nevertheless, there is a mismatch between the policy as intended and implemented and the policy as perceived by the faculty.

   The impression is widespread that research, publishing, and obtaining research grants are valued higher than dedication to the Plan. Reinforcing these faculty concerns is the undisputable fact that outside mobility and marketability are enhanced more by publishing and research than by contributing to the Plan.

   While I can think of no improvements in the operation of the Tenure Committee, I urge that its visibility be increased. The present practice of rotating members through the committee to widen the base of understanding helps, but it is a slow process and more is needed.

5. Dedication to the Plan equates with less time for research and publishing and reduced opportunity for the individual faculty member to stay abreast of advancing science and technology. As a possible remedy, WPI should institute for Plan-oriented faculty a vigorous program of sabbaticals with industry or in university research.

PROJECTS

Projects continue to be very popular with students. The level of project activity is still increasing but at a lower rate and will soon level out. At present, over a thousand students are engaged in project activity. With an average number of students per team of two, there are then 500 projects in progress. I sampled six projects--two of them I judged good, 2 poor, and 2 in between. While this may not have been a statistically sound sample, I am nevertheless impressed with the difficulty of maintaining quality when dealing with such large numbers. Yet high quality in projects is essential, not only because much of the student's education derives from projects, but also because WPI's reputation with participating industry is at stake.

The solution proposed by the panel--and I strongly support it--is the establishment of an industry-faculty Project Committee which, on an on-going basis, samples the quality of projects and provides feedback to the faculty. While I recognize the problem in recommending yet another committee activity for an already overburdened faculty, I see no other way of achieving the required quality control.

COMPETENCY EXAM

This continues to be a problem area. For the student, because the threat and actuality of failing comes so late in the program; for the faculty, because the goals and implementation of the competency exam have not clearly emerged as yet. There is lack of consensus between and within departments whether the exam should test competency or comprehensiveness. Should it deal with fundamentals or methodology? Should it be long or short? Should it be tailored to the individual student's program or should his program be tailored to the scope of the competency exam? Should the departments provide special coaching and preparation?

So far, about 300 exams have been given and 200 students have passed. This failure rate coming so late in the program, when the traditional student has long since "made it," appears too high to me. My recommendations for the competency exam are these:

1. The exam should not confine itself either to competency or comprehensiveness but should contain elements of both, i.e., it should test the student's knowledge as well as his ability to apply this knowledge to problem-solving.
2. Early in his curriculum the student and his advisor should map out a course of study and through a "written contract" establish the technical fields for which the student will be held responsible. This contract would outline a required program of courses as well as project activity. If the student has fulfilled his part of the contract, the probability of passing the competency exam should be high, much higher than the present 200 out of 300.

3. There should be reasonable consistency across the campus in the nature, length, and difficulty of competency exams. This consistency will not come overnight but should be made a long-range goal. To monitor and facilitate the attainment of this goal an interdisciplinary and interdepartmental committee is needed.
4. A program of preparing and coaching students for the competency exam, following the lead of the Physics Department, should be adopted campuswide.

GRADES

The news media have reported a national groundswell back to grades. Employers as well as professional schools (especially medicine and law) put heavy stress on grades. With today's job market and ample availability of candidates from colleges which give grades, ungraded students, however qualified, are at a disadvantage.

The students I talked to summed it up this way: "As far as inside WPI is concerned, the present system works well. As for the outside, there is need for grades."

7-WEEK TERM

The 7-week term continues to be a problem although not so serious as when first introduced. The curriculum committee has shown commendable flexibility in reverting, where needed, to the 14-week term (in the form of two consecutive 7-week terms taught preferably by the same professor). My principal concern with the 7-week term centers around the case where a major course, traditionally taught in 14 weeks, has been compressed into 7 weeks without reducing content, thereby forcing on the student a doubling of the learning rate. I have discussed this problem with learning psychologists, and I have had personal experience with crash courses. Both convince me that comprehension and retention suffer when the learning rate greatly exceeds that evolved over many years in traditional settings.

The 7-week term resulted initially from the needs of project activity which envisioned students to be absent from the campus for a full term at a time. Since then the pattern has changed. Students now work on projects part-time, taking two or three terms, and hence no longer leave the campus for extended periods. This emerging pattern makes it even easier to revert to 14 weeks where desirable.

CONCLUSIONS

The WPI Plan offers a valuable variant to traditional engineering education and has made a promising start. The first graduating class is of high caliber and sold on the merits of the Plan. Enrollments have held up and an increasing percentage of freshmen select WPI because of the Plan.

The Plan, if implemented at a high quality level, requires more faculty per student than the traditional format and is therefore inherently more costly. By how much and how to pay for it are vital questions which WPI must address urgently.

Whether the Plan offers engineering education superior to the traditional approach is not clear. Traditional schools, after all, are not standing still either but are constantly evolving and adapting to changing conditions. A definitive comparison between the two educational schemes will take years to achieve and may indeed be of interest to the NSF and the educational community at large.

Final NSF-WPI Summary Report

of

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10 June 1975

To: National Science Foundation

Re: (CoSIP) Grant GY-9353 to Worcester Polytechnic Institute

From: David Riesman

Our Panelists agreed that in making a summary report to the National Science Foundation, we would follow our usual practice of individual reports, leaving any summary of our summaries to be done, if such procedure is desirable, either at Worcester Polytechnic Institute (WPI) itself, or at NSF. These individual reports have permitted Panel members to make use of their special foci of interest and ranges of observations, and I would like to begin this report by saying something about the composition of the Panel and hence, by implication, about the general question of selecting panels to monitor governmental grants.

At the outset, I should make plain that I feel I know very little about WPI in spite of all the efforts of the institution itself and my fellow Panelists to help overcome my limitations. Although I have spent a modest amount of time at California Institute of Technology, Rice, RPI, Case Western Reserve, etc., and have intense interest in the work of high-technology companies, I still have an enormous amount to learn. I began with the four volumes of the Two Towers document; I cannot say enough for the dedication of the faculty under the leadership of Professor C. William Shipman which produced the "Two Towers" series, analyzing what WPI had been, assessing with a kind of cautious boldness what it might become. Indeed, having immersed myself in these documents, I may have been too critical in my reports of what I regard as the failure of some WPI faculty to understand the Plan, for I am, so to speak, in the business of visiting and understanding educational experimentation, whereas they are in the business of teaching electrical engineering or English poetry or whatever the case may be. No doubt, there are young recruits to WPI who have had less chance than I to read the Two Towers documents. I may even be a more faithful reader of the student paper, Newspeak, than they, for which in earlier months--the paper is now ever so much better--one could hardly blame anybody!

Furthermore, I know that there has simply been no way for me to overcome two handicaps: I joined the Panel because I was interested in the Plan and admired its ambitions; and the Panel itself was so to speak identified with "The Administration" even though we were neither stupid enough nor confined enough to avoid hearing many criticisms. But aggressively anti-Plan faculty would hardly be inclined to seek me out. And in meetings with departments, I would not want to expose them if they felt threatened by my presence. (When I commented on the relative sobriety and civility of discourse at faculty meetings, someone said to me that our Panel was a factor here: people behaved themselves more in our presence. But that itself, if so, distinguished WPI from other institutions where the opposite might be the case!)

1. The Panel

In the first of our reports submitted to NSF on December 21, 1972, I drew an analogy between WPI and a developing country--a country whose very remoteness from centers of sophistication and skepticism led to the inauguration of a Plan of extraordinary ambitiousness and scope. In my observation at other educational institutions which fall into similar categories as WPI, faculty members come from major research-oriented universities and tell the "natives" how we do it at Berkeley or MIT or Harvard--something our hosts hardly need to learn from us and which is rarely helpful. Our Panel was on the whole relatively free of such implicit ethnocentrism and snobbery. We were in the main not provincial to our own institutions, nor indeed convinced that they furnished the last word for an "underdeveloped nation." Instead, for example, Lee Harrisberger could report on how Harvey Mudd or Kansas State University was handling comparable problems; John Whinnery was familiar with the co-op plan at Antioch; Kenneth Picha had a knowledge of the ecology of private higher education in New England and its relation to its private and public competitors--I could go around the list of Panelists and report similar ability to draw on wider segments of academic experience not only in this country but elsewhere.

All of us came to WPI with curiosity, admiration for the aims of the Plan, willingness to devote our full attention to the enterprise not only while we were there but also in following documentary materials sent to us in the interims between our meetings--and well aware of the dangers any visiting team encounters of seeing "Potemkin Villages" while difficulties and obscurities remain safely hidden. In some small part, a reader of our first reports to the institution might well have concluded that we were almost caricaturing C. P. Snow's portrait of "the two cultures" in our individual reports, with the science-and-engineering-oriented members of the Panel, while seeing many of the problems of the Plan, attributing these to questions of implementation that could be solved rather easily; while from the first I myself and Bruce Mazlish of the Humanities Division at MIT were more inclined to see basic obstacles in the very design of the Plan and to believe that nothing is ever a matter of "mere" implementation, particularly when one is dealing with the characteristic idiosyncrasies, temptations to anarchism, and alternations between euphoria and despair to be found among many academicians and intellectuals, ourselves included. At the same time, each of the Panelists respected the others and the group as a whole, and in the course of our meetings, we became personally attached to one another, so that it was with genuine sadness that we have parted company as a cadre. Our differences in judging various aspects of the Plan and the Plan as a whole, as argued out among ourselves at our private meetings, and as represented candidly in our semi-annual reports, were contained within a general framework of sympathy for what has been in many ways the heroic effort of WPI to transform itself, and with respect for the judgements each of us made concerning that effort.

It does of course not follow from this that allowing the institution to select its own Panelists would always work out this way. What gave our work such leverage as it may have had, in direct feedback to the institution during and after our visits, and in indirect feedback to NSF periodically and now in this report, was the complete candor of the leaders of the Institute and especially of Dean William Grogan, who was our particular host and who, as Project Director of the NSF grant, has carried the main burden of its interpretation to faculty and students; while President George Hazzard has carried the message outside, later supplemented by Dean of Faculty Ray Bolz, vis-a-vis NSF itself, other granting agencies, the Board of Trustees (who have been considerably reconstituted and are no longer provincial to Worcester and the New England area) and the two only slightly overlapping worlds of schools of engineering and experimental undergraduate liberal arts colleges. The integrity of this leadership is one of the major assets of the Plan. I have seen enough self-convinced evangelists of educational reform in my own work on higher education to be sure that many institutions could not be trusted to put together a Panel that would combine sympathy with detachment, nor trust it to reveal to the Panel everything without exception that the Panel wanted to know, without in any way hiding difficulties and dilemmas.

To illustrate: members of the Panel soon began to feel that, if we were not seeing built-to-order Potemkin Villages, we were at least meeting undergraduates of unusual articulateness and, in general, sympathy for the Plan. We asked to meet a more random assortment of students, and this was made possible at our subsequent meetings by arranging for us to go as individuals to have lunch in fraternity houses, to visit groups in the residence halls, and in my own case by invading what many faculty members would consider the privacy of the classroom and permitting me to visit classes--I only wish I could have done more of that--prior to our Panel meetings. It nevertheless did turn out that we met mainly students and faculty who were more articulate than average, more sympathetic to the Plan on the whole, although not invariably; but even in the case of faculty, the good luck of being able to attend several open faculty meetings which occurred during the course of our Panel meetings gave us an opportunity to see and hear some of the more resistant faculty and to gain a sense of the combination of fatalism and intransigence with which they were still responding to the Plan, basically unreconciled. Yet it would be quite natural, without any conscious effort on the part of our hosts, in fact with efforts going in the opposite direction, that the students who would seek us out and the faculty likewise would tend to be those who were the supporters of the Plan, who tended also to be the more articulate even when we met students in groups--here the fraternity houses were a helpful exception.

I conclude that it would not be a good idea for NSF in general to allow an institution to which it has made a grant to pick its own Panel, even though in this case we believe the results may have justified the decision. Rather, it would make sense to ask for nominations from the institution--not necessarily only from the top leadership, for in most of these cases an institution will be divided within itself--and then to analyze the general attitudes toward innovation or toward tradition represented by the nominees and to supplement these from NSF's own knowledge of individuals who might contribute both divergent and convergent perspectives. I would say that the size of our Panel was about right; we could meet for a single conversation around a single table without anyone taking too much air time. But I would also insist that the chairman of the Panel is of the greatest importance as a guard against monopolization of Panel time by a not inconsiderable number of academic narcissists likely to be engaged in such work! Such chairmen are rare in American academic culture today: most have a laissez-faire attitude, which advantages the articulate and penalizes the shy; all the more, then, individual reports are to be preferred since one cannot count on having a chairman (a term I prefer for both sexes) who will see that everyone's voice and especially minority voices get equal air time--or count, as in our case, on a spirit of give and take among the Panelists who grew to have respect for each other's professional judgment and personal qualities.

2. The Transportability of Innovation and the Problem of Evaluation

In an earlier era, and even now in a good deal of post-baccalaureate education in the arts and sciences and other fields, reform-minded governmental and foundation officials and educators have believed that the problem of communicating the results of what might be called R&D at all educational levels was at least as serious as the research and development enterprise itself. It was widely believed, and I myself believed it, that most colleges and universities did their best to imitate the pace-setter private and public universities of world-class distinction, whether or not these models were suitable to their particular mandate vis-a-vis their student constituencies, the development of their faculty members, or the local communities to whom they had responsibility--and furthermore, that these imitations were not of the actual practices at major universities and university colleges, but of what had been the practice or was believed to be the practice currently. The two "Newman Reports" struck this note, as did Alden Dunham's volume prepared for the Carnegie Commission, Colleges of the Forgotten Americans, or my own volume of nearly 20 years ago, Constraint and Variety in American Education. I believe that at the level of Ph.D. training in the arts and sciences, these verdicts are still in general correct; changes here are intramural, specific to departments or subdepartments, and while they are spread quickly when it comes to research findings, they spread hardly at all when it comes to pedagogic or organizational inventiveness. But I believe that the story is now quite different at the undergraduate level, and that, if anything, the modes of communication of what are presumed to be admirable and hence fund-worthy innovations spread almost too quickly.

In discussions with our Panel and with our WPI hosts, I made a comparison with the "cargo cults" observed by anthropologists, where non-literate people would come to believe that the white man's goods would arrive as cargo if only the old gods and practices were totally abandoned, thrown in the ocean in many cases, and the people believed in the new gods of the white man. Starvation and chaos were often the inevitable result; occasionally, a revitalization movement occurred which saved the day, usually where a leader arose who could syncretize old and new--as the Japanese have so notably done in managing to modernize many aspects of their society while retaining the cohesiveness and support structure of older traditions.

In a situation of relatively or even absolutely shrinking resources for higher education, ever so many private colleges all over the United States have junked what they have seen as antiquated departmentalism, credit hours, chronological sequences, and opted for many features that could also be found in the WPI Plan, such an individuated instruction or contract learning, some version of pass/no credit grading, competence-based evaluations, and so forth. Some ambitious new public institutions have also followed this same route, seeking adult or other constituencies and offering degrees on the basis of external projects, some completed before matriculation at the institution.

Thus what seems to me to be required in the present climate is less undiscriminating spread of the latest evangelistic proposals for reform, i.e., the cargo cults of higher education, and more discriminating analysis of the problems faced by institutions seeking to institute reform. Indeed, one might well hope that these institutions would be given a certain protective tariff of modest invisibility while struggling with the sorts of grave and nearly intractable problems faced by WPI and other pioneering adventurers; the danger here as in other governmental programs is very much part of the American grain: hoping for too much, too soon, and not recognizing all the obstacles, and believing that good will is the major necessary ingredient for innovative redesign of curriculum.

I know that this may be and almost certainly is quixotic counsel for the institutions and for NSF itself: one needs to oversell to gain support, and then hope that the sheriff will not come around too soon! A sheriff in the form of Senator Proxmire or the recent terrible Amendment passed by the House of Representatives vis-a-vis NSF proposals, or in the form of the General Accounting Office or other government inspecting and auditing agencies.

I am not suggesting that there are no lessons to be learned from WPI, and that its historical uniqueness--and I believe it is unique for reasons I shall present in a moment--makes it impossible to examine it with an eye to what could be done elsewhere. But that eye must be informed by the knowledge of what is unique to WPI.

And here a word is in order about the general kind of educational evaluation which is built into federal programs currently and into many offices of institutional research in colleges and universities. These are mainly staffed by people trained in educational psychology, whose mode of procedure is to interview every nth student and/or every nth faculty member; I have yet to see a case where they have interviewed members of the Board of Trustees, actual or prospective employers, or faculty members at rival institutions. Thus, their research is intramural and even there, in my observation, not so much at WPI but at other innovating institutions, limited by the very mode of procedure. Neither students nor faculty are fungible goods! It does not help us much to be told, for example, that 80% of WPI students are satisfied with the new Plan. It helps us some; just as the Carnegie Commission surveys of student satisfaction in the late 1960's helped rebut the common ideologically tinged premise that "students" were monolithic, and that they all shared the antagonism made use of for propaganda purposes by the political and counter-cultural Left among both faculty and students. Indeed, the use of student complaints as leverage for academic reform is a common practice; reformers read into what students say, their own judgments as to what ought to be done. Thus, surveys do help in balancing such polemical and slanted views based on impression and on the more articulate.

At the same time it should be obvious that students do not live in isolation. Certainly not on a residential campus such as WPI. Like faculty, they form sub-cultures; and I have wanted to see any survey work done by snowball sampling rather than by random sampling to take account of this. It may be more important that 20% of the students are dissatisfied if it is these students who have been brought to WPI by the advertising of the new Plan, its allure as represented in the catalogue or by recruiters, than that 80% of a student population of lower-middle-class and often working-class origin express themselves as satisfied with the status quo, whatever the status quo may be at the time of their arrival. And of course the same is true of faculty: at WPI, to illustrate, my fear from the very outset has been that the acceptance of the Plan, occurring as it did at the same historical time that the faculty was discovering itself as a faculty and becoming more democratized--in line with contemporary trends everywhere else--meant that there was always the possibility of what too dramatically I term "counter revolution" by a minority of dissident faculty hostile to the Plan from the outset and not reconciled even today. (Especially in engineering, such faculty could use at least the alibi of professional accreditation by the ECPD or other engineering associations as the basis for their fear for WPI's future and as a cover of their antagonism to a Plan backed by the Administration.)

I have already indicated that WPI did far better in its in-house educational evaluation than other comparable institutions with which I have had experience. It is, for example, extremely important that Dr. Karen Cohen lives in Worcester; that she is an adjunct faculty member at WPI; that she had an eye for what one might term the ethnography of the institution as well as the psychological attitudes of the students she was surveying. Furthermore, the use of comparison institutions was an admirable addition to the original plan for evaluation, and since a number of the Panel have some acquaintance with one or both of these colleges (and with Illinois Institute of Technology, to which a grant was also made by NSF, with whose progress I have tried to keep in touch vicariously), thus the resultant evaluations have not been provincial to WPI as has been the more general pattern in evaluation.

3. WPI's Uniqueness

These last observations lead to my first observation about WPI's uniqueness, at least in the orbit of experimenting colleges and universities I have had some chance to examine in the last decade or so. Here is a notable case which contradicts the prevailing notion that home guard in-bred faculty tend to resist reform, while newly recruited faculty, especially those who went through college and graduate school in the late 1960's, are the wave and hope of the future. At WPI it is perhaps not too strong to say that it is the home guard loyalist faculty, led by William Grogan himself, who has spent his entire life at WPI, who are the mainstays of and the creators of the Plan. At WPI itself, I had heard the hope expressed that newly recruited young faculty would be more flexible, more adaptable to the demands of the Plan. Of this, I was from the outset skeptical. For the Plan makes such intense demands on faculty that it tends, if seriously attended to, to alter the career patterns of those faculty members who come with newly minted doctorates to the institution. For example, my first advice to WPI in recruiting social scientists was that they do their best to secure adjunct faculty from oufits like A. D. Little or Abt Associates, rather than recruit economists or political scientists trained at leading universities, for the latter would not want to engage in project work with civil engineers but rather write articles for the journals which would give them visibility and prevent their cannibalization by the high demands of the Plan. In fact, one of the innocences with which many engineering schools have embarked on efforts to "humanize" themselves has been the belief that people in the social sciences are only waiting to hear from policy-oriented engineers and natural scientists in order to respond in the latter's terms; whereas, of course, most will want to respond in terms of their own discipline and the narrow tariff boundaries in which they have been trained.

In that sense, WPI furnishes a marvelous illustration which I think can be generalized: namely, that some of the best chances for reform lie in institutions with a loyalist faculty, with no other opportunities elsewhere, who care about the institution's survival in part out of loyalty and idealism, and in part because it is the only source of their own academic survival. I should add that in my own case, one of the reasons I was happy to serve on the NSF Panel was my belief that the best chance for reform of undergraduate curricula may lie precisely in the more conservative institutions: either conservative by reason of location, as in some of the Southern institutions, or in the mountain states, or in the denominational colleges, or by reason of the mandate of the institution and the faculty it has acquired, as with WPI.

And here, WPI, so far as I can determine, really is unique. Thus, I have studied the catalogues of Stevens Institute, of Clarkson; I have visited Rensselaer Polytechnic Institute and have a little sense of Rose-Hulman, have visited Case when it was still Case, and Rice and other high technology institutions; there is none which has as in-bred a faculty as WPI, or even comes close, and none I can think of at the moment where the delay between the baccalaureate and the doctoral degree is as long as in the case of WPI where a number of faculty and graduates of WPI, took a masters there after they had started teaching there, and then perhaps got a doctorate a dozen years later at Clark or Boston University. Or have not gotten a doctorate at all. (They are tenured in by a kind of grandfather clause which was necessary if the Plan was to have a chance; but many are still assistant professors in their 40's or even older, or associate professors though they have been at WPI for a quarter century--a problem of the limited incentives WPI has at its disposal and, since its financial incentives are so limited, the need to preserve titular incentives as marks of approbation, though these are often conferred too slowly in terms of time-in-grade with the danger of losing some of the most outstanding faculty who are mobile.)

If WPI is unique in its recruitment of faculty and the corresponding insulation, it is also somewhat idiosyncratic in having been run by a high military officer at the very time the Plan was adumbrated. I myself believe that thorough-going educational reform comes from the top with leverage from outside agencies such as NSF, although support, of course, is needed from faculty, too. And thus it is not enough if an institution is to transform itself as greatly as WPI has hoped to do, to have full faculty support if one does not have support from the hierarchy, beginning with the Board of Trustees and, certainly in the case of a baccalaureate school most of whose graduates go on to direct employment, among employers as well.

This uniqueness, if I am right about the fact, of WPI, at least among private schools of engineering, is a lesson in reverse for other institutions: it suggests when not to start reforms if they are to be wholesale, rather than, for example, as at Illinois Institute of Technology, partitioned off into a separate cadre who, whatever their actual merit, may be regarded as a bunch of freaks by the regular faculty. Furthermore, while the historical idiosyncrasy of WPI implies that its entire program is non-transportable in our judgment, for here the Panel is in full agreement, it of course does not follow that specific features cannot be modified to suit the local context of other institutions, something which of course is already happening as WPI receives a stream of visitors and as our Panel itself discusses the experiment, as for example I myself did at a meeting of the Educational Staff Seminar in Washington, D.C., in January, and again briefly in a commentary on competence-based education at the American Educational Research Association meetings later this spring.

Indeed, one of the widely applicable "lessons" of the WPI enterprise is the judgment that innovation requires "thick" rather than "thin" administrations. The significance of this lesson needs underlining in an era when most faculty are vain enough to believe that, if they only wanted to, they could be administrators, since it requires only the ambition of an idiot and no special talent! Furthermore, in an era of shrinking budgets, faculty are allergic to any increase in the size of administration either absolutely or relatively, or in the compensation of administrators. Old-fashioned American anti-authority feelings here combine with envy and spleen. WPI is especially vulnerable in this respect because it had been run hierarchically and therefore required only a "lean" administration, and even though President George Hazzard has been adept at recruiting additional sources of outside support as well as maintaining and strengthening support from a more cosmopolitan Board of Trustees, he has inevitably moved into an era of co-determination when faculty and students insist on being in on decisions and when it is important to persuade and no longer feasible to command.

Even in a more participatory era, had WPI continued its curriculum, it might have managed with its present level of administration. But it is my conviction from examining educational experiments in many different milieux, private and public, that if they are to succeed they require an almost unbelievable vigilance by administrators, endless persuasion and attention to detail, and hence a much larger administration than is required simply to keep going along traditional lines. And precisely because what WPI has set out to do is so total a revamping of its whole procedure, from negotiated admissions to competence-based and project-oriented requirements for graduation, it demands more of its administration than its faculty are for the most part willing to grant, and the administration is naturally hesitant to respond to the needs pointed out by our Panel for fear of arousing further faculty resentment--resentment which could lead in the end to unionization with all that implies in the American grain for entrenched inflexibility and an adversary relation to "management." Thus, in encouraging experimentation elsewhere, NSF itself might provide a certain leverage here, as it helps inaugurate other new educational ventures, by seeing to it that recipients understand the need for a "thick" administration rather than one as overextended as is now the case at WPI. It could thus serve to legitimate, as our Panel has sought to do, further expenditures on administration even in a time of retrenchment.

I have sometimes said only half in jest that experimenting institutions need a vice president in charge of visitors! As the WPI Plan has gained visibility, it has attracted visitors and more will come, and their reception falls on the same small band who carry the enterprise forward from day to day. Thus I felt half guilty when I learned that my remarks at the Educational Staff Seminar had resulted in the planned visits of some members of the ESS to WPI in the days immediately ahead. And yet I recognize that in a situation of tremendous stress where there is still a good deal of latent hostility to the Plan among faculty (although little among students recruited since the Plan went into effect, even though by no means all of them came because of the Plan), those who bear the burdens of the Plan, both in the faculty and in the administration, need the moral support such visitors bring--need to feel that what they are doing has significance for undergraduate education in general and engineering education in particular.

4. The Overall Significance of the WPI Plan

So far, I have touched upon the idiosyncrasy of the Plan without making clear just what is unique about it. What is unique is a combination of various elements, each one of which can be found elsewhere at retail, but so far as I know, nowhere else as a total enterprise.

a. Negotiated Admissions. There is certainly nothing novel about Open Admissions: state colleges and universities have had de facto Open Admissions for a long time, and probably the majority of private colleges have had Open Admissions also, only pretending to be selective and lacking a sufficiently large applicant pool to be selective in practice: in other words, most private colleges are practicing what Parsons College, to its undoing, openly preached. But Negotiated Admissions is not at all the same as Open Admissions. It is an effort to work out with students, both directly and through their high school teachers and guidance counselors, whether WPI is something feasible for them, and whether they are capable of betting on themselves enough to take the risks of entry. As I remarked at the time of our first visit, there is always the danger of what might be called the Groucho Marx syndrome: if I get admitted so easily to WPI, is it worth attending! But under the perceptive direction of the former Director of Admissions, now at Middlebury College, WPI made a genuine attempt to ask students to answer the question for themselves, which required a much closer analysis by them of what WPI could offer and what they could offer than is true in general at the 12th grade level, where student choices are often so whimsical or guided by where they feel it is prestigeful to get in, whether to their educational advantage or not. WPI asks prospective students to look at the question of "value added" in a serious way, explaining what it is that they seek and what it is students should have in the way of cognitive equipment and of motivation in order to make a go of it. To be sure, they actively discourage students who in their judgment are not likely to succeed, for the sake of those students and for the sake of others who may be demoralized by seeking to teach them or keep peer company with them. But if a determined student wants to attend WPI, he or she can do so at risk, knowing that entry does not mean automatic advancement, let alone graduation. And in some cases, this policy has worked out well, illustrating what we all recognize: namely that while test scores and high school records are useful information to have, students may possess information about themselves which they volunteer only by making the bet on themselves that Negotiated Admissions permits. Thus there are students at WPI who were bored in high school and had poor records, but who came alive under the possibility WPI offers for individuated instruction, though of course there are also examples of misjudgment by students of their capacities either cognitively or, more difficult to assess, in terms of pertinacity without the constant spur of the boot camp procedures characteristic of traditional engineering schools.

Negotiated Admissions is by no means universally esteemed either by faculty or students at WPI. There is some belief, but little evidence, that it has lowered standards; it seems to me more likely that it has helped to bifurcate the recent entering classes, bringing WPI both some exceptionally talented students who would never have considered it hitherto, and some who might not have been admitted hitherto--although this last is hard to sort out from the near-simultaneous effort to recruit nonwhites and women in competition with more prestigeful institutions such as nearby MIT which can offer more to groups previously infrequent recruits to high technology and high science.

b. Crossing the "Two Cultures" Divide. In the United States, in contrast to other parts of the world, engineering tends to be a "first generation" calling: it is a natural port of entry for bright young men from backgrounds of modest means and cultivation, often young men for whom the basement workshop or an interest in science fiction has made it possible for them to avoid the supposed "naturalness" of coeducation in the teenage years (a love for horses plays something of the same role for women!). This recruitment to engineering schools also reflects the fact that engineering is not seen as an independent profession in the way that medicine and law are (often mistakenly) regarded by the children of the affluent who, in seeking what they so often dogmatically define as "meaningful work" mean by that phrase: "nobody's the boss of me!" While at WPI I found a handful of students who were themselves children of engineers, daughters as well as sons, this is extremely rare--in comparison, for example, with the situation in a medical school, where many students are relatives of physicians.

Faculty teaching the humanities in an engineering school tend to look at themselves with even more self-pity than is the case today with faculty generally. They see their mandate as rescuing a few among the barbarians for the truths of high culture or, in the terms just posed, asking students to make a two-generation jump within the span of a single four-year baccalaureat program. They regard it as a victory if they have "converted" a student out of engineering and into a supposedly more humane field. Even at institutions as diversified as MIT or Cal Tech have become, one can find such attitudes; as my language suggests, I find such attitudes snobbish and deplorable.

My own hope has always been that teachers of the humanities in schools devoted to engineering and science will not seek to make converts nor to create disaffected and alienated engineers. Instead, I would want them to find connections between what they do and what their students are likely to do within the many mansions of engineering and science. In the case of performing music, this is easy enough; at least among scientists and to some degree among engineers, musical performance as well as musical interest is widespread. But to get students at an institution like WPI to understand science as itself one of the humanities with the aid of the faculty in the humanities is inordinately difficult, for there are few people in the humanities who are capable of such an effort.

I can speak with personal feeling here because there is no area of my own work where I have felt less successful than in this one. As someone whose own undergraduate major was in biochemical sciences and who believes that we are still an industrial society despite our post-industrial attitudes, I feel it essential to get rid of the notion that teachers of the humanities are necessarily more humane than teachers of physical chemistry or aeronautical engineering, or that their subjects are necessarily more liberating. However, whereas in my teaching at Harvard I have found no problem at all in opening up the social sciences and humanities for students in the Division of Engineering and Applied Physics or in other scientific fields, I have been almost totally unsuccessful in getting students who regard themselves as humane, because they cannot read a table, to cross the divide over to the other side and to appreciate the magnificent achievements of science and technology. And of course I deal with a student body on the science side who in many cases have chosen Harvard over Cal Tech or Rice or MIT because they wanted to preserve the option of moving away from science or at any rate not to confine themselves to the company of fellow scientists and engineers. Altogether too many of them are converted, so that I have repeatedly complained about the "brain drain" into law and to some measure medicine (generally not today a field of high science), away from the heart of our industrial and scientific civilization.

The students at WPI are not the highly ideological, relatively affluent students of the Ivy League, although of course there are a few exceptions; the temptation of many of them is to dismiss the humanities as "cultural bull" or, much as they regard industrial management, as a "soft option" for the weak in heart. Nevertheless, despite this initial resistance, I have been impressed by the degree to which, in part reflecting the new Plan, WPI students in the course of our three years of visits have become more at home with the humanities and have even found arenas of contact which make the humanities more than a kind of gloss for prospective managers or for cocktail party conversation when one cannot avoid encountering females! This is because WPI has managed in spite of its low salaries and, in the world of the liberal arts, low repute and visibility (as distinct from its far wider orbit of recognition in engineering) to recruit faculty in the humanities of rare dedication who are not aiming to make converts.

To illustrate: one of the most imaginative cross-disciplinary courses given at WPI was one on Light and Vision several years ago, which dealt with vision from the point of view of optics, of perception, and of painting. Furthermore, faculty teaching the history of science and technology have been among the best go-betweens in crossing the "two cultures" divide, for by giving students a sense of the past of their own fields they have transcended the contemporaneity evident in most scientific writing, where citations rarely antedate the last decade. Science and engineering thus become part of the fabric of history in a way that makes them more alive for their practitioners.

I am far from saying that WPI has accomplished what has failed elsewhere, but it has done far more in the humanities than was evident in our initial visits; my awareness of accomplishments here springs from seeing the syllabi of jointly taught courses such as the one on light and vision, as well as visiting classes in the humanities area. Indeed, when one of the leaders of the WPI faculty who also teachers English at Clark declares, as he did in a private conversation, that he preferred teaching his WPI students to those at Clark, I felt that this was a real triumph for the WPI Plan, and not simply the inverse snobbery of an extremely gifted scholar.

_c._ Some of the classes I have visited have been taught by what I have referred to as the "home guard loyalists" of WPI, who have been there a long time, teacher-scholars who are not looking for the next chance somewhere else. At other engineering schools I have visited, people in that position would be resentful; and I have been impressed at WPI with their indomitable energy and dedication, their genuine interest in students and their development, and their lack of evangelical desire to convert students to supposedly more noble callings. They do not feel that their own status depends on sending students to graduate school in their own specialties.

Yet it does not follow that students at WPI of their own volition do not seek to shift their fields away from engineering and science even at a time when graduates with a B.S. from WPI can command salaries in many fields of engineering, chemical engineering for example, higher than those paid to the assistant professors who teach them. Because of my own interests, I have probably had more contact than most of my fellow-Panelists with such students who, in their last year or two at WPI, have come to consult me both at the institution itself and in Cambridge about their futures. For one thing, quite a number have gotten interested in education itself as a field of work because of the enormous amount of discussion evoked by the Plan, and reported upon with increasing accuracy in the pages of the student weekly, as well as in discussion among students and between students and faculty. Other WPI undergraduates, as would be the case elsewhere, have joined the *Drang nach* medicine and law; still others, combining their engineering training and their newly acquired interests, want to go on in programs in architecture or in urban and regional planning. But there are still others who, discovering for the first time that it is conceivable that one can make a living as a writer, want to go to schools of journalism or to enter Ph.D. programs outside of the area of science and technology.

As is indicated by my remarks just now, I view such students with ambivalence: naturally I help them pursue their own goals as best I can, and at the same time regret that they are leaving engineering rather than staying, as the WPI Plan would hope for them to do, to stay in engineering and to change the image of the calling by their very presence in it--once graduates emerging from such training begin to form a "critical mass" in the field itself.

Still, the presence of such students at WPI, who stay on there rather than transfer--and some of course do transfer--makes for a far more lively intellectual life at the institute both for faculty and students than would have been the case in an earlier, more monolithic era. Thus they are not a loss to WPI even if they are a loss to the hoped-for hybrid of "humane technologist."

d. What is a "humane technologist"? The phrase just used grates on me, I must confess. It assumes the very point at issue, namely that technologists are not humane, and by implication that people in the humanities are humane. This has not been my experience with either cadre. Indeed, snobbery vis-a-vis engineers in non-engineering schools and among the children of the elite would not be permissible if it were ethnic, but seems legitimate because it is merely occupational.

Terminology aside, it is clear that what the new Plan aims for at WPI is an engineer with training in the basic sciences who is at the same time conversant with the social and human consequences of what was once assumed to be automatic growth and progress. One of the greatest difficulties I see in the WPI Plan or in the effort to transfer some of its components elsewhere lies right here. In the original design, it had been hoped that the great majority of students would perform so-called IQP's, Interactive Qualifying Projects, in which there would be both a social and a technical component.

In my judgment, this aspect of the program assumed, as do so many currents of innovation, that "interdisciplinary" work was feasible: after all, there has been so much talk about it, why should it not be feasible? In fact, it is a rarity. It comes about when faculty at home in one discipline make themselves scholars if not researchers in another. Most faculty members in experimental institutions who claim to be interdisciplinary are in my observation non-disciplinary or, what is worse, anti-disciplinary. Most courses which are termed interdisciplinary in those institutions which have abolished departments are simply additive: a civil engineer talks about his or her specialty, followed by a political scientist who talks about that specialty, while each pontificats about the work of the other--and meanwhile the students are supposed to put the two fields together! Thus much that passes for interdisciplinary teaching and research is shoddy, more so in my judgment in academic institutions than in industrial or governmental research centers, where people must work together on a topic and really learn each other's trade in the course of solving concrete applied problems.

The IQP was based on the notion of such problem-orientation. But where does one today recruit faculty in the social sciences who are problem-oriented and not merely rhetorical? Certainly it is not easy in my own field of sociology, and it is perhaps even harder in economics, where as my own Harvard department would readily confess, a Ph.D. who goes to work for the Federal Reserve Board or even the Council of Economic Advisers is thought to be downwardly mobile intellectually as against taking a position at a major university where the discipleship of his mentors can be carried on! Precisely because the social sciences are relative newcomers to academia, without either the consensus of the natural sciences or the canons of tradition of the best humanities, they have sought to establish themselves as "pure" and deprecated applied work--I speak here of the major centers of learning. And when they have gone in for applied work, they have done so with the shallowness of a neophyte, often combined with the zealotry of a convert: we are all familiar with the spectacle of the Nobel laureate who is suddenly an authority on race, war, pollution, population, and everything else!

WPI has not escpaed vestiges of such trivialization of the complexities of genuinely cross-disciplinary projects. I have examined enough projects, and so have my fellow Panelists, to be convinced of this. (I recall on one of my first visits a student telling me that he was doing an IQP at St. Vincent's Hospital, where in fact a good deal of fine work goes on by WPI students, which had a "social" component because he was developing an electronic heart pacer--it was "social" because it would help mankind.) Rather wisely, in my judgment, the IQP was not made compulsory, although the overwhelming majority of the students do engage in one. With the strengthening of the Division of Interdisciplinary Affairs, the intellectual base for IQP activity will surely be improved at WPI--but I know no institution that has done this easily, and WPI faculty are realizing that the reading of a few books by Lewis Mumford or Jacques Ellul is not enough to create a "humane technologist."

That this recognition has long since dawned at WPI is represented by what seems one of its most admirable features, namely the Washington Project, which takes a score of students every term to Washington and locates them in (mainly) government agencies to deal with problems of transport, environment, occupational health and safety, etc., etc., as apprentices to those already working in the area. Such off-campus work is carefully supervised at WPI itself, first in helping to prepare the student before the Washington sojourn and then in weekly meetings during that sojourn and efforts to assimilate the experience afterwards in the form of a written report. Some of the reports I have seen are admirable. They establish what I have long believed: namely, that able undergraduates can do as serious work as most graduate students, and as inventive.

Although Washington, D.C., is full of interns and apprentices from many different universities all over the country, it is far from saturated. No city in the country has more highly qualified holders of terminal professional degrees, the Ph.D. or its equivalent, who would enjoy a chance of part-time teaching of a student who could be helpful on a project. Because its own universities are not among the world's most distinguished, these students can compete with area students for the attention of this reserve army of the pedagogically underemployed. And the latter can justify their teaching, which they must enjoy, because the students actually produce, as the project our Panel has reviewed suggest that many of them do.

Moreover, if one considers how provincial are the origins of WPI students, not only in terms of social background but also in geographic terms, the Washington sojourn means as much to them as, for example, the Stanford Year in Tokyo means to Stanford undergraduates--it may be at least as much of a culture shock and it takes the New England students away from what I have jokingly referred to as "laundry range," which is the orbit within which most of them live.

Furthermore, confined in Washington with their two faculty members who are now regularly rotated, and each other, and beginning to establish contact with students at American, or George Washington, or Georgetown Universities, they can form a kind of intellectual fraternity to compete with the more collegiate fraternities which still dominate socially at WPI even though they no longer dominate culturally or psychologically. (I am not in this remark taking the usual position of the highbrow academic that fraternities in collegiate life are bad. I am just saying that the life of the fraternities at WPI has not been notable for its breath or cultivation, and that this is not inherent in the fraternity mode of life.)

It is unlikely under present circumstances that more than a fifth of the WPI students will have a chance for the Washington experience, and all our Panelists recommended that there be other centers of this sort set up in a large geographic orbit, in industry as well as in government, where groups of WPI students can work on projects and thus delegate some of the responsibilities of instruction to what are in effect adjunct faculty. Yet we also recognize that the very effort to create such off-campus settings is time-consuming, and this leads to my next observation, about faculty.

5. Faculty

I indicated at the outset my belief that the majority of WPI administrators and faculty who developed the new Plan did not fully appreciate what they were getting in for--else they would never have done it. They underestimated the long-run costs and difficulties, for example, the difficulty of finding faculty and students capable of mastering interactive qualifying projects at a high level in conjoint areas. Moreover, they were inclined to believe that, once the Plan reached a supposed steady state, difficulties would minimize whereas from the first I have thought they would intensify. (I believe the very concept of "steady state" a doubtful one in human affairs: when my colleagues of the Carnegie Commission on Higher Education started talking about the coming "steady state" in higher education, I insisted it would be very unsteady indeed, and that entropy was a more likely outcome than stability.)

Indeed, many of the criticisms I have made of the Plan in my series of reports and in personal conversation and correspondence with WPI officials and faculty have been in terms of the inability to recognize at the very outset what it might mean both logistically and psychologically when all students, as is now soon to be the case, will be new Plan students. It is a staple of social science criticism and evaluation of educational and other projects to point to the long-run unintended consequences of reform actions, when the euphoria or "Hawthorne Effect" of the experiment has waned,* and when the diurnal realities of the so-called steady state have made themselves fully felt--and when the visitors attracted to the novel and the innovative are off looking at something else.

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*Since writing the foregoing, I have benefited from the draft report of my fellow Panelist, John Whinnery, and entirely agree with his judgment that the Hawthorne Effect is something to be cultivated in educational experiments, rather than to be seen as an obstacle to evaluation and understanding. Indeed, one might plan for a series of "Hawthorne Effects," even when one begins a highly demanding set

6. The Incompleted Revolution

It will already be evident to whomever reads this memorandum that the writer thinks in terms of analogies and many of these may seem far-fetched. However, as someone with more than a nodding acquaintance with recent Japanese history, I have repeatedly thought of the Meiji Restoration, which was actually a revolution from the top, when pondering the origins and prospects of the new Plan at WPI. For in part, it was the need for survival of a private engineering college at a time when all private colleges, even the most affluent and overapplied, are suffering budgetary deficits that led WPI administrators and faculty to consider the famous set of Two Towers reports in which the Plan was first adumbrated and by means of which it was discussed, while it was a hierarchical and loyalist structure of WPI that made it possible to believe a faculty could transform itself in a radical way envisaged in the Plan. Like Meiji, the Plan has an extraordinary sweep about it: the very timetable is altered, with seven-week instead of the traditional fourteen-week terms; the old requirements and sequences are deprived of legitimacy, an effort is made to save faculty time and to put students more on their own mettle by modular IPI programs and by a fair amount of experiment with television teaching; there is a further hope of making a reality of the Worcester Consortium which, like other consortia, exhibits what Freud called the narcissism of minor differences, as well as the resistance of students at the Consortium institutions to make the effort to travel even to a neighboring college, much as WPI students have found it hard to uproot themselves to go as far as Washington, D.C. (There is also almost nothing in the way of a set of faculty sub-cultures in the Worcester area in which faculty in the consortium colleges have much intellectual commerce with each other; though Worcester's chief industry next to the Norton Grinding Wheel Company is probably higher education, its work force is spread in all directions, from Cambridge in the east to Amherst in the west, and there is little contiguous association even within, let alone among, institutions. And, of

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of educational innovations, so that momentum and morale continue, even though e would not want to create an atmosphere of "permanent revolution" on a campus which gave faculty no sense of security and emotional balance. The attraction of good students by the positive feedback of the Hawthorne Effect to which John Whinnery refers is itself self-sustaining, making WPI a more attractive place for its faculty as well as for fellow students.

course, there are great differences of status and distinction among the institutions, with WPI at a disadvantage in the liberal arts milieux of New England higher education, even while it also suffers competition not only from the excellent University of Massachusetts programs on the Amherst campus and perhaps eventually on the Worcester campus, but also from the increased stature of Southeastern Massachusetts Technological University and the new combined Technological University in Lowell, Massachusetts.)

But survivalism alone would not have brought about the Plan, any more than Commodore Perry's invasion would have brought about the Meiji Restoration. There has been throughout a tremendous idealism at WPI, a belief that one can "overtake and surpass" the academic leaders and do something which will be of genuine national consequence. Certainly, what at a conference of Carnegie Corporation Trustees I first heard George Hazzard describe the WPI Plan, I was overwhelmed with its daring, and eager to see for myself how this had come about and what it was like in practice.

There is no need here to repeat the elaborate history, detailed in part in the Two Towers volumes and still alive in the memory of the Plan's advocates who are still among its stalwarts at the institution. But what needs to be understood is that, though the Plan was discussed in endless caucuses and meetings, its full ramifications were understood and are perhaps to this day understood by only a minority of the faculty. Or rather it is perhaps fairer to say that the Plan was not understood by the faculty until it was well into its second year, and that for many of the faculty and students, first one feature of the Plan and then another was seized up as The Plan, when in fact none of these features alone was essential to the Plan.

a. The Seven-Week Term. In November, 1972, when our Panel first visited WPI, the student paper had for weeks been filled with imprecations against the seven-week plan by faculty and students alike. And to some of my fellow Panelists the seven-week schedule seemed to be the main issue and even hazard of the Plan. But so far as I could judge on that first visit, the seven-week term had nothing directly to do with the basic ideas of the Plan, although in fact to move to a seven-week plan seemed to me an ingenious effort to force the faculty and students to consider the realities of the Plan almost as a kind of basic-training ritual of hazing. For one thing, the seven-week plan was a way of shaking up the routines of what had often become repetitive classroom lectures to obediently inattentive student audiences. (In fact, one of the dismaying failures of the

Plan has been in the inadequacy of the architecture of the buildings to accomodate the kinds of discussions and seminars the Plan calls for; it is disheartening to attend a seminar in a basement laboratory with students sitting in classroom rows behind fixed desks with the professor up front behind his fixed and gadget-filled desk, so that students in the fourth row cannot hear the question-and-answer exchange between the professor and the student in the first row. At last, in the new design of the old Salisbury building there is an effort to create seminar rooms more appropriate to the needs of the Plan. This is one of every so many illustrations of underestimation of the costs in physical capital of the Plan; the costs in underestimation of human capital, whether at the level of the administration or the level of faculty are, as already adumbrated, much more serious.) To me, the seven-week term was a signal to the faculty that they were teaching their subjects in an excessively factual and slack way with a great deal of noise or redundancy in the channels of communication. To move from fourteen weeks to seven weeks did not mean, as many professors in fact thought--or interpreted it to mean--that they should talk more rapidly or try to crowd in extra section meetings, but instead that they should reorganize the subject matter of their courses, to see what was the basic set of theories they wanted to convey and then to illustrate, allowing the students themselves to fill in the necessary gaps.

The seven-week term meant an equally drastic shift in routine for the traditional WPI student. It altered the diurnal cycle by reducing the number of daily class hours, thus permitting concentration on a few subjects, which seems to me altogether admirable; it forced the students to pace themselves from the very beginning rather than wait till the end and then cram for the examinations; it asked them to begin assimilating material instantly, and discovering whether they were in trouble instantly, so that they could get help before they fell too far behind. The belief among many faculty that the seven-week term was the Plan, and that it was impossible to comply with its requirements--and one heard many horror stories of students who had missed a week and therefore could never catch up--was for me the first sign of what might be thought of as the incipient counter-revolution against the "revolution" from the top which had put the Plan into effect. When students did not "get" the material, anti-Plan faculty blamed the seven-week terms; they told the students in no uncertain terms how much they could teach them--if only they were allowed the old fourteen-week span; many students panicked while other students were dilatory, nonplussed by the lack of required routines and unable to force themselves to work independently in the fashion demanded by the Plan. Anti-Plan faculty could lend support to such students by side-of-the-mouth comments about how they could not possibly teach their subject in seven weeks (without making a frontal assault on the Plan).

They were sufficiently persuasive so that some of our Panelists thought at the outset that the seven-week term was a mistake. I thought instead it was a stroke of genius. It made clear that the Plan was a revolution, that it required re-thinking one's subject matter and stripping it to its essentials, and altering one's relations to students so as to put them on their own. And yet I thought that nothing like a majority of the student body would be capable of such self-paced and self-motivated instruction, nor would the now heavily-tenured faculty be capable of adapting itself to the requirements of the Plan, symbolized by their failure to understand that the seven-week term was not the Plan, but only a symbol or symptom of its expectations.

Thus, from the very beginning I was forced to think about alternatives in the form of fallback positions in case the Plan proved too ambitious. Would it be possible, I asked in my first report, to think of creating an honors college within WPI for those faculty and students capable of the self-motivated, highly individuated learning, with its heavy demands for mentorship rather than lecturing, that the Plan required? Would in the current egalitarian climate such an honors college seem elitist not only to those excluded but, as was soon made clear, by those included? Would it be possible for an institution as small as WPI to operate two simultaneous programs: its traditional one and the new Plan? In fact, it was doing just that when we first visited, for the majority of students were not yet on the Plan, and I was here anticipating what would occur when the so-called steady state was reached.

At time went on, I became persuaded that the idea of an honors college was infeasible. The majority of faculty was neither pro-Plan nor anti-Plan; it was ambivalent, looking back to the good old days and yet realizing that they could not be restored. Major supporters of the Plan, moreover, were torn between that interest in their graduate programs and in the undergraduate features of the Plan--an unresolved dilemma to which our Panel returned again and again. Only a minority understood and fully supported the Plan, and they did not want an honors college for this ran counter to their idealism.

These pro-Plan faculty did not believe it would be possible to select in advance those students capable of profiting from the Plan and, with the pedagogic evangelism of redeemers, they thought it would be possible eventually to attract enough pro-Plan students to WPI to create a large "critical mass" who wanted the Plan and were capable of it, and that only a laggard few might fall by the wayside.

I could not gainsay their judgment that it was difficult to tell in advance who could profit from the Plan. For this is not a matter of test scores, but of self-confidence, pertinacity--qualities of character for which we have no national system of measurement. (Indeed, several years earlier I had talked to friends at Educational Testing Service about the growing vogue of independent study in experimental colleges and even in traditional ones, and said that in addition to the regular SAT and MAT scores, it was now important for colleges to have tests for motivational qualities: for example, for lack of narcissism because narcissism makes independent study difficult, since one must already be a genius and dare not test oneself; for pertinacity in the face of failure and frustration; for ability to proceed without the affective support of faculty or the sanctions of faculty either. My ETS friends threw up their hands in despair at the prospect of such subjective measures, which would have to be done by projective tests whose unreliability on a mass scale is notorious.) Yet I am convinced that we must move in this direction if we are to have more experiments of the WPI sort and better judgments of what sort of students can profit from them and what sort probably cannot. Of course I am not saying that one should do away with the test scores we have now: below a certain threshhold of ability to handle words and figures, students are incapable of profiting from WPI at any level; but it is also true that students with extremely high test scores can be among the most narcissistic, have endured the least frustration in school in terms of inability to perform (although they may have been bored silly) and hence be poor bets for independent study.

Periodically for several years, I would bring up my honors college idea, or its sardonic alternative: a Veterans Administration hospital on campus for the student and faculty casualties of the Plan. But it soon became plain that such a division both within and among faculty and students would be demoralizing and that it would require a different administrative structure--and we have already referred to the thinness of administration for running a single innovative enterprise, let alone several.

What happened to the seven-week term illustrates the alternative course that was not so much chosen as stumbled into, namely, concessions to what I have referred to as the incipient counterrevolution against the Plan, to pacify both legitimate criticisms and obdurate adversaries--adversaries from the outset who seldom understood the Plan rather than those who objected to it, as did a number of faculty and at least one member of our Panel, on grounds of lack of rigor and inability to meet the requirements of professional engineering accreditation.

(This latter fear is, in the judgment I have formed and that of the more knowledgeable engineering deans on our Panel, largely a chimera: accrediting groups are today tending to lean over backward to favor innovation even when it is not very good, as George Arnstein has pointed out in several publications; and while the engineering fraternity remains somewhat more conservative, it seems doubtful that the WPI Plan will not be given every opportunity to prove itself since it so largely meets many of the criticisms of the engineering profession that have come from some of its leading figures, including those who play prominent parts in the ECPD.) At any rate, what was done was to make concessions in those fields where either on realisitic grounds of the nature of the material, as was claimed to be the case in mathematics, or on practical grounds of recusant faculty, permission was granted to run two seven-week terms back to back with the same faculty person in charge, so as in effect to restore the fourteen-week term in some of the arenas of greatest resistance.

A few members of the mathematics faculty deserve a separate comment. Someone teaching the humanities at an engineering school such as WPI was before the Two Towers reports was very clear that he or she was teaching "service courses," a labor of love or a labor of last resort as the case might be; rarely finding students prepared to become disciples in the teacher's own field, not that I myself regard seeking out such disciples as wise--as point I return to--and occasionally discovering the pleasure of teaching the humanities to "innocent" students for whom these have not been spoiled by previous pedantry in a liberal arts college. The mathematicians tend to be a service department of another sort altogether. They are not exactly scientists, but in their general intellectual level often quite rightly see themselves as superior to mere mundane scientists: they have been the aristocrats of the scientific side of C. P. Snow's "Two Cultures"; yet at an engineering school they are generally as much service faculty as people in English or fine arts: they are preparing students with rather low-level mathematics to do the minimum of work needed to get by in their physics or chemistry or biology courses, perhaps go on to medical school, or into engineering--almost never into mathematics. I first noticed in studying Oakland University in Michigan that one of the leading proponents of faculty collective bargaining was a mathematician, an idealistic person who felt frustrated by the rather low level of students to whom he was teaching a subject they could not escape--a captive audience--and also a person with the ample time that mathematics allows its able devotees for extramural activities. The problem is further complicated by the fact that mathematics often turns out to be what I have sometimes termed a "beauty queen" field, in which people either make their mark very quickly or decide that they will not; then they have the choice of becoming dedicated teachers, administrators, activists, or all of the these combined. Even active research in mathematics is so demanding that it takes little time, although tremendous intensity. (This is one reason perhaps why mathematicians are often available for chamber music, along with natural scientists.)

No other field has quite as great a consensus about what is good work; no other field is inclined to regard the so-called real world as beneath contempt, so that even theoretical physicists can be looked down on my mathematicians because physicists have to put their hands on matter at least in their heads!

So far, as should be obvious, I have been talking about "pure" and not about applied mathematicians. WPI, of course, has both. Their problems are not identical and they should not be grouped in the stereotypical way that may be suggested by the foregoing remarks. For reasons already suggested, applied mathematicians tend to be regarded as less gifted than so-called pure mathematicians, and thus are not only in a service position, like the rest of the mathematicians, but in a subordinate one. Yet their task is extremely difficult: it must be very frustrating to try to teach applied mathematics either by individually programmed instruction or by any other more traditional device to students with skimpy high school backgrounds in mathematics in a situation where the seven-week term may prove a genuine obstacle and where changes in the level of effort put forth by students have accompanied the Plan, at least at the outset, when a number of students saw the Plan as an opportunity to goof off because, after all, weren't they supposed to proceed at their own pace?

Correspondingly, it is understandable that some mathematicians have been among those at WPI for whom the Plan has been seen as lowering standards which were not especially exalted to begin with. There is great sensitivity at WPI to the lowering of test scores, especially MAT scores, since 1968; this is so even though if one goes back and takes a longer time span and looks at comparable colleges, WPI test scores have on the whole fallen not much more than these have nationally. And among the union activists at WPI, I expected and did find several mathematicians as well as others; I have already indicated my judgment that unionization (though presently attractive only to a minority of faculty) would be a genuine threat to the fundamental moral (or, as some would view it, immoral) basis of the Plan, which requires of its faculty adherents endurance of a 70-hour week at the very least, rather than a contractually arranged set of "contact hours" and an elaborate set of grievance procedures to consume whatever time is left!

I have mentioned mathematicians because, whether pure or applied, they do tend to feel second-class at an engineering school, even though they may be first-class in their own quite proper sense of themselves. They come in for criticism from their colleagues in the science fields when they do not manage to teach freshmen and sophomores to do the work necessary for an engineering school--even while, as I say, they watch their ablest students, who can do this work with one hand, go on to applied fields such as computer science which bear the same relation to pure mathematics as, let us say, orthopedic surgery does to biochemistry.

It should be clear that I have mentioned mathematicians only illustratively and also that they are not a monolithic group in any way. Furthermore, I should make clear that the criticisms of some articulate mathematicians arise in a setting in which under the Old Regime there was very little if any criticism by faculty.

The problems of what is moral and of the sources of morale go much deeper than any single department. The very lack of visibility of many WPI faculty well before the Plan, coupled with the lack of visibility produced by the demands of the Plan, means that many faculty will decide that the union is their only security, since they are stuck with WPI and vice versa, and must improve their conditions there rather than going somewhere else if dissatisfied. The union thus offers a vehicle to register and collect all the resentments built up by the relatively low salaries of the faculty, relative not only to what baccalaureate graduates can receive, but also relative to the elite private colleges and to high salaries of the University of Massachusetts in general and its medical school at Worcester in particular. Furthermore, since many WPI faculty had prior to the Plan counted on a steady income from consulting at least one day a week--the permissible, if perhaps not the actual time--and since under the conditions at once of democratization and of the Plan, something has to give, it is often the consulting which gives way, WPI faculty may have suffered a large absolute as well as relative decline in income as a consequence of inflation on the one side and the Plan on the other. This is so in spite of efforts by the Trustees and the administration to keep up with inflation at least partway, in spite of the difficulty under which even the wealthiest private colleges are currently laboring.

The difficulties under which the Trustees are laboring to keep WPI solvent not only currently but in the future and hence a magnet for philanthropic beneficence is not understood by many faculty. Our Panel happened by chance to attend a faculty meeting where someone proposed cutting down the size of the student body to those who could cope with the Plan, and with the requirements for preparation in mathematics and other fields necessary for success in the Plan. This could be done if the Trustees would draw on endowment for an interim period until WPI could recruit enough new Plan students to justify the Plan. It was clear to me that WPI could not possibly afford the loss of tuition such a shift in recruitment would involve; even today it depends on its draw of students who do not know about the Plan, or do not take it seriously, but consider it the "available college," in that part of New England which regards private higher education as having more prestige or at least more intimacy than its low-tuition public counterparts. (Of course, low tuition does not mean low subsistence, let alone compensation for income foregone.) No faculty on this occasion offered to take a cut in salary until such time as WPI was attracting students worthy of the Plan!

b. The Interactive Qualifying Projects. One place where mathematics would have been useful, although it might have prevented the Plan ever coming into effect, would have been some rather simple calculations of the number of inventive projects which would be required once all students were on the Plan: major qualifying projects within one's field; IQP's for those who did them, second major-field qualifying projects for those not doing IQP's; competency-based examinations. If one adds together the inventiveness required to think up projects for the less ingenious and inventive of the students on the one side, and the inventiveness required to provide so-called competency examinations for the entire student body on the other side, especially if students fail one or more of these on the first try, the end result is staggering. WPI is not the only innovative college not to have made that calculation. Thus I had visited Hampshire College in the Connecticut Valley the day before our fall Panel meeting at WPI, and I had appreciated from the initial Hampshire literature and from this all too brief visit the extent to which providing innovative examinations coupled with individuated evaluations for required First Division courses as well as senior projects for all Hampshire students would overtax the logistical energies of the Hampshire Registrar, and the psychological energies of many Hampshire faculty and students. Even to schedule these examinations at Hampshire has turned into a nightmare.

Some of my engineering fellow Panelists thought of this as a mere issue of implementation, whereas for me it has been a fundamental problem of the Plan from the very outset. And this was especially true of the IQP, with its expectation of interdisciplinary work in cooperation with the still unformed Social Science Division, which would have its own disciplinary tracks and traditions once it came on board. At its best, as in the Washington Project, as I have already said, the IQP works admirably well for the most part, although even in the Washington Project there are bits of shoddy work. But the vast majority of WPI faculty and students seem to me incapable of envisaging what an IQP should be like, and even the summer study project which was held last year and which produced some admirable models vis-a-vis both the humanities and the social sciences, could scarcely begin to satisfy the requirement of providing students with topics on which they could do interdisciplinary projects.

To be sure, the theory of the Plan required that students think these up themselves with help from a mentor. But it should be remembered that these are students for whom narcissism is less of a problem than humility: they think of themselves that if they were really good they would not be at WPI at all, except for the small number who are attracted by the Plan and who could have entered MIT or Cal Tech; they are rather docile students, accustomed to being led, not to leading the way. There is no crime in that; the country could use followership as well as leadership; but the Plan is designed to turn out leaders, innovators, inventors.

At the outset, despite some idealism which wanted everyone to have an IQP, it was not made a requirement, only an option; but the hope was that eventually everyone would do an IQP. There is much effort to persuade students to do just this. Yet allowing some to get through who have not done IQP's is a concession to the requirements of the moment. But I am sure that the Plan devotees hope eventually that all students will do IQP's. They may also hope that all courses will be on the seven-week term, which facilitates project interludes in a way that the fourteen-week term necessarily destroys them.* (In this connection, I might add that the internal WPI evaluators, polling the faculty, as well as straw votes at faculty meetings, make clear that a slight majority of WPI faculty favors a ten-week term, not a return to the fourteen-week term nor the seven-week term, but a compromise which satisfies nobody, does not fit much of the Consortium, and so far has not been pressed even by its numerically predominant advocates.)

c. The Competency Examinations. If the seven-week term was the symptom of malaise on our Panel's first visit, the competency exam served a similar symbolic role on one of our later visits. Eating lunch in the fraternities in our effort to meet more representative or typical students, each member of the Panel was regaled with horror stories of how this or that student who had done nearly four years of serious and solid work would not graduate because of failing an idiotic examination which had not been well prepared or fairly administered. (In my own case, I heard such stories, but also the story of a student who, having failed the first time, was coached and supported by faculty to make sure that in spite of anxiety, he would not fail a second time, and he did not.) What impressed me about these stories was their rarity more than their severity, and the degree to which faculty went out of their way to try to invent examinations which would at once test student ingenuity faced with novel situations, such as they might face in the practice of engineering or a calling in the sciences, and yet examinations which would not be unfair to the preparation the student had received. Since more than a single faculty member was responsible for both inventing the examination and administering it, ordinarily on a departmental basis, again I was struck by the logistical immensity of the task, as in the example already mentioned at Hampshire College. How many inventive examinations were the faculty capable of, before the fraternities piled up their record of old competency examinations or until term paper companies took over the task in the many innovative colleges which are on some form of competency-based program!

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*Whinnery's draft report, just received, notes that if certain courses are given every term, one can combine 14-week courses with interludes with work on projects, although this imposes still another demand on faculty.

For indeed, the measurement of competence, once one gets outside the most limited areas such as simple mathematics or verbal fluency in a foreign language, is a task of inordinate complexity, as other agencies of the federal government are discovering which have supported CBE programs in teacher education and in other fields, many of which are also mandated by state legislation. Can one indeed measure competence of an engineer over less than a lifetime? One can measure various components: articulateness (where there seems to our Panel to have been definitive improvement at WPI over the three years of our visits); ability to use the resources of the institution on one's own, where it our impression there has also been improvement; and yet the ability to work under pressure that such an examination requires and to know how to pace oneself without become prematurely exhausted is not a task to which WPI students, or for that matter most academicians, are accustomed. It is only people in practical life who have to work this way! To the extent that WPI faculty act as consultants, they too must meet deadlines (something in which I myself have been deficient in writing my semiannual reports to WPI). Most of us procrastinate when we can, and indeed our examination of the IPI (Individually Prescribed Instruction) work at WPI shows that this often happens with students who lack the prod of daily recitations--and there is probably a small minority, an irreducible minority probably, of students for whom machine instruction is for psychological reasons impossible, even though for most students it removes the humiliation of failure on the one side or the feared arrogance of speed and success on the other side.

d. Intersession. One of the advantages of the seven-week calendar in its first installation was the ability to create a winter and spring inter-term period, such as many institutions have adopted. At many of these places, I have asked the question I have asked of founders of new magazines: what will you put in the seventh issue? For again it is a problem of the well of inventiveness among faculty on which one can depend: the first several Intersessions draw faculty out in the most extraordinary ways and prove immensely rewarding. Thus it is rewarding for students to discover that their feared professor of physics is giving an Intersession course on Chinese cooking, or that a chemical engineer is teaching them how to build harpsichords, or that a professor of history is taking them to Florida to do oral history among the residual indigenous residents of the Florida Keys. Faculty and students discover each other in new ways, increase the range of mutually shared interests, break the routines of formal relationships which are particularly striking at WPI because of the near total lack of any non-classroom residential contact between students and faculty. (Here again, on this last point, budgetary considerations are important: to buy up the fraternities and turn them into subcolleges with masters would be far beyond the WPI budget even if it were politic on other grounds. And the residence halls have been used only in limited degree as ways to socialize students into the new Plan either by the use of WPI upperclassmen to tutor underclassmen or by the use of faculty as residents to try to create an intellectual subculture among the hard-working but on the whole unintellectual student body.)

It was my impression that erosion had overtaken Intersession also. Half the students signed up for the last round, and quite a few did not take it too seriously. Still, it served a purpose. It draws out freshmen and sophomores, while providing juniors, seniors, and faculty a special time to get themselves organized concerning projects and competency examinations. The mini-courses of Intersession are supplemented by upper-class students in the library and laboratories as they prepare to organize or wrap up their project work.

Here and elsewhere much depends on definition: from one point of view one could say that the Intersession is running out of steam; from another, that it has found new uses, especially for upper-division students, not originally contemplated. Yet it has been a good idea; and as with magazines, there is no reason to have a seventh issue--no law that requires that, once started, such efforts go on indefinitely. Here they have gone on in part because new functions have been found for them, and if this is not regarded as erosion by Plan idealists, but as adaptability, Intersession may still be viable for some time to come.

e. Grades. Over the last twenty years, my co-workers and I have visited and in some measure studied a number of more or less experimental undergraduate colleges which have dispensed with grades and put in their place evaluations. Reed and Sarah Lawrence have done this traditionally. The University of California at Santa Cruz has recently reaffirmed this policy in the face of increasing student and faculty objections. Evergreen State College in Olympia, Washington, does not give grades. Neither does New College in Sarasota, nor Hampshire. (Indeed, during the political-pedagogic movements of protest of the late 1960's, grades were moderated in many institutions, and in many more "grade inflation" has occurred as it has at my own institution, where the average grade is said to be B+, which gives already [illegible]aged Harvard students an immense advantage over colleges such as Welles[illegible]mith, or Chicago which still take grades seriously.) In all these instances, I have emphasized to faculty and administration the need for great vigilance on their part to explain their systems of evaluating students to graduate schools and to employers, and to make plain to students the variety of responses they are likely to meet when they come with nontraditional transcripts to a variety of institutions for further study. In other words, if one abandons the traditional scorecard of grades, however meaningless that scorecard may have become, one seems to me obligated to do much more to see that one's students are not prejudiced by finding the places or persuading the places to which students go that they are not taking undue risks in basing their acceptance on evaluations and in taking the time necessary to assess evaluations. (For example, I took on myself the burden of helping persuade some of the departments in the Faculty of Arts and Sciences at Harvard and also the Harvard Medical School that it was possible to read a New College, Sarasota, transcript so as to determine whether a student was serious or not by looking at the courses taken, quite apart from the evaluation.) Yet some colleges which depend on evaluations, such as Antioch has traditionally done, have allowed them to become sloppy to the point of meaninglessness, so that one may read at a ridiculous extreme that "Johnny is relating better to people now," or that "Jane has found her identity," or similarly possibly interesting but usually unhelpful statements when one is competing for admission to overapplied programs at the post-baccalaureate level. If one is to get rid of grades, in other words, one has to work much harder at serious evaluation both for the sake of the student's own understanding of his or her assets and lacunae, and for the sake of giving the student a reasonable platform on which to stand for post-baccalaureate entry. And this of course is one of the many areas in which innovative programs make so many cumulative demands on faculty that one cannot possibly speak intelligently about "steady state." Indeed, to keep examinations from becoming mere comprehensives, designed to insure that students take the courses of one's own departmental colleagues as a kind of senatorial comity, and to write evaluations which are not redundant and meaningless requires from faculty an almost saintly devotion and the very kind of self-paced motivation (as compared with the compulsory rapid grading of exams) which the Plan requires of WPI students.

Our Panel, like the institution itself, has been of more than one mind with respect to grades. The wholehearted devotees of the Plan, both among the students and among the faculty, appear to believe that grades would create an atmosphere of invidiousness and of motivation to work for grades rather than for true learning that is inconsistent with the basic aims of the Plan. They may well be right. Yet we were repeatedly presented with evidence that there are in fact grades at WPI, and that the real issue is the number of steps between graduating with distinction or taking a course with distinction and simply getting by. Many students apparently decide that since they will not attain "Distinction," they will be satisfied with a passing grade, so that there is no motivation for the so-called "B" student to put out more effort than the minimum, once he has decided that he cannot attain the maximum. If such a student were doing the minimum in one or another course in order to do the maximum in those which particularly engrossed him, I would see no harm in this, but a great advantage--this was the reason I myself believed that at my own institution taking one course on a pass/fail basis was desirable in addition to my vain hope of getting humanities students into the sciences--the hope referred to at the outset of this memorandum.

Most of us are not saints. If we have evaluations, we will try to translate them into grades by comparing them with those of our fellows. If evaluations are poor, grades are almost sure to return at WPI--they may return anyway.

In a sense, this is another erosion.

Grades raise another issue by implication, namely of the time taken to reach a certain level of competence. In a competence-based program (or in the jargon of the day, competency-based), it does not matter how long students take to reach the objective but only that they do so in the end. For many purposes, this is admirable: it allows the slow learner, and often slow forgetter, to take his or her own time to attain proficiency rather than placing a premium on speed. As I have already said, such procedures avoid humiliating the slow learners, as IPI instruction does, or boring the quick ones. It avoids wasting faculty time in repeating material which the students can repeat for themselves as many times as required, until they have mastered it, step by step. Still, of course, no one should underestimate the amount of faculty time taken in creating the necessary programs or even in shopping for those that are on the commercial market. Here again, the WPI Plan in all its ramifications--and IPI is not an essential feature of the Plan, although many students and faculty at the outset so regarded it, or even saw it as the very heart of the Plan along with the seven-week term--suggests the degree to which the Plan absorbs what I have referred to above as human capital resources.

But there is more to it than that. We are now in an era of what might be called the sanitized transcript. The Buckley Amendment is a factor here, as is the fear of litigation which was already present before that Amendment. Intimidation of faculty by students is common in the elite colleges, uncommon at WPI, but as one abandons all requirements, faculty compete with each other for student traffic and one way they do so is to offer more reward (in the form of flattery, grades, or sexiness of presentation) for less work. That this has not yet happened at WPI is testimony to the point made at the outset, namely that in my judgment experiments have their best chance in more traditional milieux. Nevertheless, it may for some purposes be important to know how long a student took to reach a certain objective, as well as the fact that the student reached it. One may not necessarily prefer the speedy student who can cram to the slow but steady one who masters the material, whether or not there is a connection between speed of learning and forgetting--and I would maintain that forgetting is almost as important as learning, and that it is a mistake to believe that cramming is sinful and that learning to cram, which men are more capable of in the present climate than women generally are, is only a form of low cunning. Many situations in life require cramming--others require patience; it all depends. Thus I would like to know how many trials a student took, or how long a student took, to reach an objective, and this information is denied me by the type of transcript now available in many competence-based programs.

7. Is Erosion Serious?

When I spoke of erosion as the alternative route taken by WPI to cope with the extraordinary demands of the Plan put on administration and faculty, one of my fellow Panelists said that the Plan was not so to speak engraved in stone, but was like the American Constitution in being subject to interpretation as new circumstances developed. This is of course correct up to a point, and so recognized by all concerned. And yet because the original aspirations of the Plan were so heroic and adventurous, growing as these did out of discussions among a relatively small number of WPI faculty and sustained under the leadership of Dean Grogan, each concession to reality has some of the quality of surrender. I have had the impression from the very outset that there are faculty who, as it were, are waiting in the wings for this Plan to pass as other novelties pass, meanwhile maintaining as best they can their often very good routines. And while last summer's program is indicative of the really extraordinary strides that can be made in faculty development even in a single summer, the Plan is simply too demanding to allow a department chairman, for example, to socialize neophyte faculty to the expectations of the Plan and to teach faculty what almost none learn in graduate school and few on the job, namely how to be mentors rather than traditional lecturer-teachers. WPI is trying to create a new breed of faculty from its own membership and from a considerable number of new recruits, the latter trained in graduate schools which have made no effort whatsoever to alter their procedures to meet the current market for Ph.D.'s--and I include here the few Doctor of Arts programs I have looked at, which really do not do this job either, and which would require a very considerable lead-time among graduate faculty to learn how to implement.

At least at the beginning of our series of meetings, it was the common thought among some of my fellow Panelists and some WPI staff themselves that the "answer" to the dilemmas posed by the Plan was an altered structure of rewards and incentives, so that faculty would be paid and promoted on the basis of their skill at the new tasks demanded by the Plan: skill at mentoring, skill at creating IQP's and making arrangements for off-campus projects such as the one in Washington or at St. Vincent's Hospital or others; or learning how to administer examinations that tested competence rather than comprehensiveness, or fanning out to graduate schools to explain the Plan to the would-be recruiters of WPI graduates, etc. Yet such responses to the problems posed by the Plan have always seemed to me mechanical at best and self-defeating at worst. For one thing, many faculty, whether exhausted or not, do not want to be captive of WPI because they have been so devoted to it, nor should WPI want to maintain such exhausting schedules for its loyal faculty as to render them captives and to leave WPI subject to moral estoppel even when such faculty should be let go. For another thing, it seems to me inconceivable to create a community so saintly that people will be judged on the basis of their actual performance as against their pretended performance, or one in which department chairmen will not seek to aggrandize their departments by exaggerating the loads individual members carry in comparison with those carried by other departments.

All this would be the case even if WPI were purely an undergraduate institution or one which, as our Panelists uniformly held, limited itself to Master's of Science in Engineering and was sternly contraceptive when it came to allowing the rise of new Ph.D. programs. Yet such contraceptive advice comes with a bad grace from Panelists who hail from prestigeful institutions, as does contraceptive advice when offered by the United States to the poor nations of the globe or the poor parts of America itself. It appears to say that we ourselves have made it, and now don't you interfere with us by trying to make it too. True wisdom or not, it is not likely to be accepted--and our Panel's advice on this subject was consistently disregarded, even though it was congruent with reports of Graduate Committees which had been appointed in recent years.

For one thing, the "law" of "the more, the more," operates at WPI as elsewhere: many of those who are engaged in research and who need graduate students to help with that research are also among the most able stalwarts of the Plan. Are they to be told that they are not allowed to maintain their professional visibility? Are they not to be encouraged to use their graduate students as transmission belts or intermediaries to help students with their projects? We had no good answers to these questions even though it appeared that in most cases the graduate students at WPI were mostly master's candidates from Taiwan or Kuwait or India who were in no hurry to complete their programs and were sometimes less than adequate in the role of transmission belts vis-a-vis WPI undergraduates.

The very nature of the funding process of innovative programs, including such dramatically daring ones as that at WPI, assumes that institutions can themselves carry them on from their own resources once they are launched. But consider an institution which has few funds to reshape its traditional classrooms to a new mode of teaching, or to permit faculty who have exhausted themselves in service of the Plan to restore their professional visibility and self-confidence by sabbaticals for full-time research either on or off the campus, or which can compensate them in salaries for money lost in consulting fees, and it will be evident that financial and emotional costs accumulate even while resources shrink. It was already evident to me from the last several visits of our Panel that some of the originators of the Plan had left or were planning to leave, while others--and this is far more dangerous--had as it were resigned, feeling they had served more than their Peace Corps term and seeing every concession, for example the introduction of two new Ph.D. programs during the course of our Panel's work (each justified in its own terms), as a defeat for their own insistence that the undergraduate program should have full priority and that WPI cannot afford even the mild schizophrenia of distraction by graduate programs.

It should be added that it is the Plan Loyalists who have taken on themselves the task of discovering and succoring those first-year students who have been attracted from distant places--from Galveston, or Oakland, California, or the Twin Cities--by the literature of the Plan, only to arrive and discover that most of their fellow-students come from no further away than Pawtucket and are at WPI because MIT turned them down and RPI is not that much better and further away! While it is true that these students help reward the faculty who in turn are their informal mentors, it is also true that this is one more demand on faculty whose home life suffers just as their professional life suffers--and no amount of talk about rewards and incentives is an answer to such dilemmas which all of us face. The situation is further aggravated because those who care about the Plan and are in fact its initiators are as I have said many of them old-timers at WPI, while both the President and the Dean of Faculty are relative newcomers who in effect inherited the Plan and yet are its public beneficiaries in terms of their own national visibility, especially that of the dedicated but over-extended President. These loyalists tend to feel that their services are taken for granted, and what is involved here is not, as I have said, a simple issue of promotion and pay, but more intangible ones of symbolic reward and responsiveness--of understanding of what they are up against and of the intricacies and intractabilities of the Plan.

8. A Preliminary Estimate

Continual slight erosions, cumulative in effect, seem to me more likely than counterrevolution. But the latter is not to be ruled out. Arbitrary acts of administration--and I mean acts which are regarded as arbitrary by an increasingly self-governing faculty rather than acts which are without reason or purpose; that is, I am talking about faculty perceptions which in American academia are generally more than slightly tinged with paranoia--may lead to tilting the balance in favor of unionization especially if relative wage rates continue to fall, for example if a new oil and energy crisis should hit New England with its heavy penalty falling on educational institutions. Inflation erodes confidence generally; it has diminished confidence in the management of the endowment by the Trustees, and in the fairness of the distribution of benefits and penalties among administration, faculty, and professional staff. And everything depends, of course, on a continued flow of students and here, as I have said earlier, the general fate of private colleges for the long-run future seems to me bleak, so much so that WPI's survival and even growth in enrollments seem to me as much to the credit of the Plan as to the general revival in the market for graduates with a B.S. in engineering, particularly if the baccalaureate degree is in a specialty in demand at the moment.

Yet given all these perils, some of them only barely visible at present, would it be just to say that WPI should never have started on the Plan? I hope these remarks have made it plain that this is not my judgment. It is precisely because the Plan started with lofty ambitions that it has achieved as much as it has accomplished. I frankly did not think it would last as long as the three years of our Panel, but well before that a crisis would occur which could not be remedied even by concession or what I have referred to as slight erosion. In the dawn's early light, the Plan is still there, still in major part uncompromised and relentless in its demands on faculty energies and student talents. And it seems clear that for the best students, WPI has provided a better education than they would have received at the comparison colleges, and that the faculty themselves have learned more than they would have even at engineering schools of higher reputation and greater national visibility prior to the Plan. One could even say that by demanding more than seemed reasonable to me at the outset one would raise the level to a point where one would end up on a higher plateau.

To create an honors college like Plan II at the University of Texas, or the subcolleges of Michigan State, or the E3 program at IIT, is no great trick, even though I think it a valuable accomplishment. But to reform a whole institution and an entire set of fields is in contrast unprecedented, and in my judgment could only have been undertaken with a certain innocence, and by people with a dedication to the institution rather than to their specific disciplines such as one generally finds only in the residual denominational colleges. As remarked at one of our Panel meetings, WPI is trying to be the Amherst of private engineering education without either Amherst's endowment, its faculty, or its student body. By making the attempt, it transcends what Amherst continues to do very well--for Amherst sends now an overwhelming proportion of its students into medicine and a smaller proportion into law, but very few to deal with the industrial and technological infrastructure of American and world society. The Amhersts cannot live unless the WPI's thrive. Or to put it in terms of government agencies, NIMH cannot spread its blessings unless NSF takes chances.

And among the assets that WPI retains in spite of erosion are above all the candor with which our Panel has been received, to which I referred at the outset--a candor which also means that neither faculty nor students are misled as to the costs and requirements of the Plan, even though they may misperceive the Plan because of the limitations of their horizons or their personal interests.

WPI might best serve on the one hand as a warning to other experimenting institutions as to the long-run costs of any experiment, and on the other hand as an indication that it is possible to seek to transform an entire institution, even one noted for its traditionalism, to create a new "product": graduates who will enter engineering and science with the cooperative spirit that comes from project work, the selfconfidence that comes from mastery and competence rather than serving time in courses and accumulating credits and grades. But precisely because WPI starts with a base of tradition and a traditional student body, this achievement is all the more impressive.

And it would be totally unwarranted if the candor with which it has opened itself to scrutiny from the Panel were to harm its chances for survival in competition with institutions whose self-advertising has not been handicapped by outside observers skeptical of extravagant claims! I hope and believe our Panel was helpful to WPI, not only in allowing the airing of specific problems and grievances, but also in indicating the awareness by the Panelits of the bravery of WPI's Plan and the importance even of small incremental steps toward its development, modification, and in bits and pieces, propagation.

9. An Interim Note on the Problem of Long-term Assessment

In 1968-69, Dean Benson Snyder, M.D., of MIT, went to some major medical schools and graduate schools in order to interview students who had been MIT undergraduates a few years earlier, in order to get from long discussions with them, some sense of their feelings about the Institute, how it had prepared them for their present work, and how they thought it had prepared them for the work and life that lay ahead. Naturally, such impressionistic assessment is short-run; but in the hands of a skilled clinician such as Benson Snyder, it can yield important results, especially if one carefully selects the students to be interviewed, looking at "straight arrows" and the more offbeat ones, those who have gone on in science and engineering and those who have followed other paths, at students who have done impressively well at MIT and at students who have done less well, etc. Our Panel of course had no such opportunity; I had myself interviewed several recent WPI graduates who are in their first year of graduate school, in one case at Harvard and in the other at MIT, one of whom had elected the Plan and the other not, both unusually articulate, and I have also had contact throughout the three years of our visits with students whom I had met on our first trip, thus having a chance at least to get a glimpse of their development within WPI--although it is obvious that in all such cases it is hard to separate out the developmental process that would have occurred under any circumstances, and the "value added" by WPI in all its infinite variety.

Indeed, so immense is that variety even in a relatively small institution, and even when all undergraduates are on the Plan, that I feel our Panel, no matter how candid our hosts nor how probing our biopsies, could only gain a rudimentary knowledge of the full range of WPI. To illustrate: although the Plan is entirely an undergraduate one, and although I have discussed in this memorandum potential conflicts between graduate programs and the undergraduate Plan, and although we heard reports and read reports by various committees on graduate education, we met virtually no graduate students, nor did we find any evidence whatsoever that, except for whatever advantages consortia offer, graduate education had been thought about as innovatively as undergraduate education has been, even though for the long-run future of American academia, reform of graduate education may be even more important than reform at the college level. And studying as I did on every trip the roster of WPI faculty, and making serious efforts to meet new ones on every trip, we still often found ourselves with the same hosts with whom we had begun: Institute stalwarts and Plan stalwarts, and on attending faculty meetings realized how many there were whom we had never even seen.

Correspondingly, I am sure I must have seemed to my WPI hosts, as I know I did to fellow Panelists, dogmatic at the very outset about the problems of the Plan, drawing as I did on experiences with innovative undergraduate enterprise and applying such experience no doubt in a too preconceived way to the very different situation of WPI about which, contrary to the situation of some of my engineering colleagues on the Panel, I knew nothing whatever until my meeting with George Hazzard three years ago. Hence I cannot urge NSF readership too strongly to take all that is said in this memorandum as tentative in the extreme, exploratory and far from definitive; much more day-to-day work would have to be done at WPI, more students who had graduated followed up in their careers, more faculty who had left interviewed as to why they had left (something I have been hesitant to do even where I have some suspicion about possible reasons related to the Plan); one would also have to avoid the situation, unavoidable in the form of our entry, of being somehow identified with "The Administration" by many faculty who are at best indifferent to the Plan and at worst biding their time in hostility and grievance. I might add that I say this about the latter without meaning to sound pejorative; I hope I have made clear how many problems the Plan does present, and how many "I told you so's" the initial Plan opponents could now rightly proclaim.

There is a further element in the time-span of assessment, and that has to do with what appears to be an increasingly bifurcated student body. The students who have sought me out during the hour or so set aside on each visit for private appointments with Panel members have tended to be those who were attracted to WPI by the new Plan without knowing much about the instituion--in fact often attracted from afar; they wanted advice from me as to where to go to study, for example, policy science, or education, or even how to break into journalism. Would they carry into these careers any of the values acquired by having attended an engineering school rather than an equally demanding private liberal arts college? (In some cases, the benefit is clear: I remember one student who planned to enter patent law, a field in which even the lemming-like rush to law haw not yet led to overcrowding, because it requires truly technical skills as well as legal and forensic training.) Many of these students had had a lonely experience at WPI: they had arrived "too soon" before a "critical mass" of like-minded students was available to support them, or at least were grouped residentially to support them, so that they had no way of finding each other--they were far less apt to join fraternities than the normal run of WPI students for whom the Plan was at best a makeweight in their decision to come. Or in many cases, made no decision to come but would have had to make a decision not to come.

And this bifurcated student body leads to another item of faculty load which was almost surely not in the calculations of the original planners: whether measured by test scores or by more impressionistic assessments, the WPI student body is today more heterogeneous than it was prior to the Plan. Indeed, as I have already suggested, many complain about students who do not come up to the old pre-1968 WPI standards--ETS has a dozen explanations as to why this might be so, including inadequacies in the high schools, permissive child-rearing, endless television-watching, etc., etc. At any rate, the heterogeneous student body forces faculty to spend more time advising the new Plan students who are ill at ease with the general run of more traditional WPI students. But it does not diminish the load from the latter group, who are rendered insecure precisely by the Plan and perhaps by their fellow, often more articulate, new Plan students. It is these latter students who worry about competency examinations, about the absence of grades, the deficiencies in the traditional structures which have sustained them and which originally led them to choose what seemed the safe course of an engineering school as against more open alternatives. Heterogeneity means ever so much more difficult teaching and, as already indicated, a much heavier load of advising. But it would seem to me unlikely that WPI will ever fully transform itself at the undergraduate level, any more than it is likely within the lifetimes of its present faculty, to do so at the faculty level. It will retain the "dual economy" characteristic of Indonesia or Japan and to a lesser degree, even the United States: the high-wage economy of the advanced, unionized, technological industries, and the low-wage economy of the less fortunate. It is tied to the latter on the faculty side by tenure and obligation, and on the student side by tradition and above all by the need for tuition, for if WPI should lose 100 students even this coming year, it might face the grave risks of insolvency that have already inundated many private colleges, experimental or otherwise.

Again, this is why one can hardly speak of reaching "steady state"!

Yet it would be equally mistaken to conclude from my comments that the Plan has produced merely discombobulation at WPI or the oscillations between euphoria and despair that I have so often seen in experimenting institutions. My fellow Panelists are not wrong in emphasizing the extraordinary quality of what has been accomplished. On each of our visits, we have met with faculty committees--part of the new selfgoverning developments--which have impressed us by the seriousness of their deliberations and the quality of the faculty serving on them and drawn from all fields and epochs of recruitment at WPI. Whether it is the Committee on Academic Policy, or the Committee on Tenure and Academic Freedom, or the Committee on Appointments and Promotion, or the several graduate committees referred to earlier, these groups have worked under the most excruciating pressures, political and personal and polemical, and have done so uncomplainingly and, in my judgment, capably, in addition to all the other burdens which this memorandum suggests the dedicated WPI faculty member shoulders. There is not a single visit at which I have not met, in addition to our particular faculty hosts, who have become our friends as well as our hosts, faculty members at WPI previously unknown to me who have impressed me as individuals of high intellectual caliber in addition to their institutional loyalty. Given the fact that many faculty either came to WPI as undergraduates or came there as their first academic appointment, well before the Plan began, and then were tenured in, I would have expected even more resentment of "The Administration" than exists, more misunderstanding and misperception of the Plan, and more jealousy vis-a-vis those faculty members and administrators who had the opportunity to address the Panel and, in some cases, meet with us socially. When as a Panel member I had an opportunity to meet with the individual departments, I chose those outside my own area of competence, Civil engineering for example, or life sciences, meeting only once with humanities and social science faculty on an early visit. And on each of these occasions I met unusally capable individuals whose record either in terms of degrees or publications would not be impressive in the national academic marketplace. (I feat this sounds condescending; it is meant simply to be factual.) Some of these individuals took part in the summer study program already mentioned, and others will do so next summer; their willingness to learn is exemplary--as illustrated also by what is said about Intersession. Their concern with and knowledge of individual students is also striking. Some have established contacts in the sciences at Clark, some in the humanities at Clark and at Holy Cross--hardly any at Assumption or other area colleges. Many have kept themselves intellectualy alive by consulting, rather than as scholar-teacher-academic-researchers.

I have spoken of grievance and paranoia, and mentioned these qualities as now almost endemic in American academia. Yet on nearly every visit I have either attended a class in the humanities or talked to an old-time faculty member in that field who, as I have said earlier, would in other institutions feel himself to be a second-class citizen in what had ended up as a second-class career. Instead, these individuals have retained an enthusiasm for teaching students who are often unresponsive, for whom the humanities have been a sideshow at best. Precisely in the humanities, WPI has been lucky or shrewd or both in a good deal of its recruiting.

What I am suggesting is that there are many hidden assets at WPI, and a reader of our biannual reports is likely to observe that mine have tended to grow somewhat less gloomy over time, although still I would suppose somewhat more pessimistic--as in the C. P. Snow paradigm already mentioned--than those of my colleagues from science and engineering. This is the result of making such repeated discoveries of quiet worth in the unsung as well as in the visible WPI faculty.

Above all, there is Dean William Grogan who, in the face of all that has been said about mistrust and feelings of being aggrieved, maintains an extraordinary control of all the details of the Plan intellectually, and an emotional hold alike on old and new faculty at WPI. I hope he will not mind my making public the phrase I used for him at our first meeting, namely, WPI's Harry Truman. In saying this, I explained that I belonged to that small minority of liberals who did not regard the succession of Harry Truman to the presidency with dismay, but rather with instant admiration for the extraordinary abilities and courage of a man who had seemed so ordinary to many of his fellow, more sophisticated Americans. There are other "Grogans" at WPI, old-timers who seem deceptively ingenuous to the visitor. Such men have the devotion of faculty at WPI who are as fashionably sophisticated as colleagues at my own institution. No doubt, strains are developing in this coalition, just as they did in the Democratic Party which Truman managed to keep together in 1948. I can only hope that Dean Grogan will be permitted more terms of office before the relaxed dynamism he brings to his task becomes, as all human energies must, eventually depleted. For I can only repeat that the administrative corps is thin and over-extended, and I see no ready platoon of replacements at any level--but as I say this, I think of some of the unsung stalwarts already mentioned, on the scene as William Grogan was on the scene, who fathered the Plan and saw it through and who, while willing to make realistic concessions, are unwilling to surrender its dramatically essential significance.

Final NSF-WPI Summary Report

of

Dr. John Whinnery

REPORT TO THE NATIONAL SCIENCE FOUNDATION

ON THE WPI PLAN

Contribution from John R. Whinnery

June 1975

I Introductory Comments and Overall Impressions

It was clear at the last meeting of the Advisory Panel that there is a good deal of consensus among Panel members concerning the overall progress in implementing the WPI Plan, and in overcoming the many difficulties met so far. There was also general agreement on some of the major problems to be solved. I shall consequently be brief in giving my interpretation of the part on which I think we agree, and then expand some points for which I have special concerns.

I strongly share the feeling, brought out by George Pake* in his summary at the meeting of April 26, that the success of the Plan so far is much greater than any of us would have predicted following our first meeting three years ago. There is a spirit, pride, and justified self-confidence among the graduates and other students we met that signals success in achieving the most important objective of the program. This seems confirmed by the results of the surveys reported to us by Karen Cohen and by the random, although admittedly limited samplings taken by Panel members in various ways. The articles in Newspeak, refreshingly concerned with educational matters in contrast to the pages of other student newspapers I know, also provide a measure of the students' concern with learning.

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*Several references in this report are made to the reports of George Pake and Dave Riesman. Reports of the other Panel members were not available to the writer at the time this report was prepared.

Of the problems to be solved, the most important overriding issue seems to me the question of resources to carry the full plan with the same enthusiasm through the next few cycles of students. Of the specific features of the Plan needing attention, the matter of Competency Examinations is most urgent. The matter of Projects, which is working much better on the whole than any of us predicted, and which I now see as almost the key to the success of the Plan, must not be ignored because it is working reasonably well. This feature must continue to be strengthened and used to integrate and strengthen other Plan features. I will comment on these points in more detail later in the report.

Before coming to the comments on specific features of the WPI Plan, (in Part IV) I will give some comments on educational innovation in general (Part II) and on recent trends in engineering education (Part III). Since this is not the place to give a reasoned, well-documented treatise on these two complicated subjects, they will have to be interpreted as personal views, primarily useful to make clear the biases from which I start. The final section (Part V) will give some specific recommendations for WPI, NSF and any succeeding Advisory Panel.

II Some Comments on Educational Innovation

The search for the ideal educational experience, like Plato's* search for the truth, is in some ways easy and in some ways hard. It is easy in that one cannot miss the goal completely, and hard in that one cannot attain it perfectly. (Of course in both cases it is possible to miss completely, but like Plato*, we are thinking of reasonable attempts.) The point is that there is a wide range of workable educational patterns, and it is difficult if not impossible to determine the optimum for an individual, and much more difficult to do so for a group. I continue to be amazed that the graduate program of my Department accepts students from literally hundreds of schools in dozens of countries representing a wide range of educational philosophies. Nevertheless, after some period of adjustment, representatives from nearly all systems are able to perform competitively.

The goal of education as I see it is to stimulate the students' interest in their subjects, to strengthen their abilities to reason, to make them aware of the interrelationships among a variety of subjects - technical, scientific, humanistic and societal - and to provide the students with some fundamentals from which to start. In a profession such as engineering, it is necessary also to develop some skills such as the abilities to use formal mathematical models, the computer, and precise electronic and mechanical instruments. Most important for rapidly changing fields is the goal of developing a habit of continuing study since the half-life of present engineering information is estimated as about five years.

If we accept the above goals and the inference from the first paragraph that the attempt to optimize should be brought to the individual level, we understandably find the focus in most innovative programs on the individual, with the ideal of a program tailored to individual needs, and a tremendous amount of individual attention along the way. This can absorb any amount of time if carried to the extreme, and even then one cannot be sure it is really the optimum for any student. Thus to make such programs workable with finite resources, the "best" solution is usually to develop small interactive groups of students, as is done to some extent naturally at any university with living groups or other institutions in which students with common interests get together. Some schools (I believe one experiment was at the Pennsylvania State University) have tried to formalize such group interaction by having a graduate student as group leader of ten seniors, each of whom was group tutor and advisor of ten juniors, and so on. Groups of five or so seem better. At WPI a good deal of group interaction at about this level is occurring through the search for project topics, and in the carrying out of group projects. The point is that such use of this kind of educational resource is not only essential if innovation is to be effected with limited resources, it may also be one of the best forms of educational experience for the students of concern to us. In looking at the faculty-student ratio at WPI, there does not appear to be the ratio commonly thought to be necessary for individually-stressed education, but if the resource of the individual student (self learning) and of groups of students (group learning and advising) can be utilized, it can be possible. Success in this respect will be one of the most important results of the Plan.

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*At least I thought it was Plato, but in checking for the exact reference have not been able to find it. Perhaps it's from another source but the point still seems worth making.

If optimization of an innovative experience is difficult, measurement of the degree of success is even more so. Ideally we would like to follow the graduates of a program, to find where they work and what they have accomplished, their attitudes towards themselves, their employers and to society, and to relate these data to the basic education they received. The first problem arises from the time delay between the measurement and the program, so that corrective action on the basis of such results is too late. But there are always other influences (often including excellent on-the-job educational additives after the experience to be evaluated) that make it difficult to separate variables. For this reason more immediate measures must be sought. In this respect the program of evaluation at WPI seems one of the best I know of. The formal study by the evaluation team, with the fortunate development of control schools, sensitivity to informal samplings of student concerns, and a careful following of the plans and opportunities of current graduates give essential if not complete information.

The intensity of this evaluative effort must of course be considered a part of the experiment, since the measurement always has an effect upon the experiment (Heisenberg's Principle in physics or the Hawthorne effect in social experiments) but this is not always bad. There is always a proper worry concerning any sociological experiment if any percieved positive results are simply due to this Hawthorne effect. But it is one of the mechanisms by which one can get positive attitudes started. Then there can follow additional positive feedback effects. The excitement of the experiment in this case attracts good students, who will help attract other good students *if they are generally satisfied with their experience*. It is this last proviso that must be watched, together with the danger of overshoot if the positive feedback goes to far; and of course there is the tendency to faddishness that seems to affect the educational community and which may cause it to leave a successful experiment for a new and presumably more exciting one. The point is that the Hawthorne effect is a part of the experiment, and can be utilized positively, but corrective action must be taken promptly to avoid excesses in attitudes by students or educators to make certain that the program remains a sound one. Thus the final point of this section is that if a program is truly innovative and hence a true educational experiment, continuing corrective action is necessary as the results of any experiment are evaluated. The difficulty is that this argument will be used by opponents of an innovative plan to steer it always back to the old and traditional course. It will require much wisdom to avoid the extremes of "no change in the original concept is possible" on the one hand and "let's get back to normal on the other."

III Some Comments on Trends in Engineering Education

It is common to think of the period prior to World War II as one of "handbook engineering" for engineering colleges, the period for two decades following as one of "scientific engineering", and the last decade as one of "societal engineering." Each of these terms are vast over-simplifications, although they do represent certain concerns of the respective periods. I had a very conventional undergraduate engineering program in the '30s, and although I have been critical of it on many occasions, reflection about it reminds me that most of the instructors were concerned with our understanding the principles underlying various devices and systems, although they also spent time on what they understood to be current engineering practice with respect to these devices and systems. This part of the approach is not all that different today, although in my Department the examples are transistors rather than vacuum tubes and A/D convertors rather than motors (although, ironically back to to motors again!) With respect to societal concerns, engineering has always been fairly responsive to the priorities set by society at any given period, whether it happens to be defense, space exploration, environmental improvement, energy utilization or low-cost manufacture. (A cynic may say that this is because money is appropriated through the political process of setting these priorities.)

The true revolution following World War II was in the move to graduate education. The number of U.S. engineering doctorates* increased from 100 in 1940 to 1200 in 1962. Fortunately there remained a strong industrial as well as academic demand for such doctorates, and I think this helped to inject a sense of reality into the doctoral programs. Also fortunately, the Masters programs did not become "failed Ph.D." programs as has happened in some fields, but retain high validity and are exactly the right level for a large number of the employers of engineering graduates.

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*Data from J. M. Pettit and J. Gere, "Evolution of Graduate Education in Engineering" J. Engin Ed. V54, p57 (1963).

The "revolution" of the last decade has been a much more difficult one and at this writing is unclear as to outcome. There has been much work and even more talk directed toward the setting up of interdisciplinary programs among engineering departments, and between the schools of engineering and other campus departments and schools (law, political science, environmental design, public health, etc). These are directed toward the presently perceived societal concerns. Such interdisciplinary programs are extremely time consuming and difficult if they are to be more than an undigested mix of disparate elements (as David Riesman points out so clearly in his summary). Thus there are some important successes but many participants are discouraged by the failures or at least unclear results of the efforts. Projects seem to provide the best mechanisms for working between fields. Thus the Interactive Qualifying Projects of the WPI Plan can be an important element of this national effort.

One general trend of the last decade is the nationwide trend to more "flexible" curricula, with many if not all of the choices left to the students. This movement was partly because of student pressure, but mostly because the growth of knowledge made clear that no large part of this could be required in a given curriculum -- hence the feeling that the particular part chosen for stress is not important so long as it serves the general educational goals. This trend was overdue but it too may have gone too far. At least there are some problems. For one thing, the results are not as different as many people hoped. Most schools that I know which have such curricula publish lists of courses for students interested in a certain subject - computers for example. The majority of students seem to follow such lists as they always did, or at least use their options to avoid one or two especially disliked subjects or instructors. Quite a few use all of their options in the field of their specialty (the computer major taking all the computer courses he can find) thus becoming more narrow rather than broader as the designers of such plans generally intend. Some do use their choices to make a broad program unique to their interests, but here prerequisites often limit the depth to which they can go in subjects outside their specialty. Good advising can help with the last-mentioned problem, and can help others depart constructively from the recommended lists. Truly effective advising programs, including participation by advanced students, is essential to make effective use of the potential in these curricula. And there do remain problems of lack of understanding of these programs by some employers and accrediting examiners, although the majority have shown sympathy, understanding and even enthusiasm for such programs.

IV Comments on Selected Aspects of the WPI Plan

The Plan is the totality of many separate elements, clearly described by William Grogan in his report to the National Science Foundation of March 6, 1975. As David Riesman points out in his comments, no one feature of the Plan can be said to be unique. On the other hand it is probably not necessary to have every present feature to attain the goals of the Plan. (See my comments in Part II concerning the lack of uniqueness of any innovative program.) I will comment only on selected features of the Plan as explained earlier.

A. The Projects. Not just one but two projects are required. The major qualifying project may be thought to be equivalent to the senior thesis used in some schools. In addition an Interactive Qualifying Project is strongly recommended, although a second purely technical project can be approved by the advisor. Projects are very good educational devices, but ingenuity and hard work are required to generate ideas for projects and to supervise them. At the end of our first few Panel meetings it seemed clear that only a few of the faculty members understood the magnitude of this commitment, and many Panel members doubted that the commitment could be met. At our last Panel meeting we reviewed projects from this last year, and although there were obvious variabilities in the levels of various projects, it was gratifying to find that the logistics of organizing the required number of projects have been met, and that many are of very high quality. The interactive projects resulting from the Washington Center represent especially good educational experiences. The projects arising from the cooperation with St. Vincent's Hospital also seemed to us of high quality. There were other good ones generated by individual faculty members. There were weak ones also, which was troublesome, but in view of the accomplishments in this short period and obvious steps which can be taken to improve quality, the overall assessment is a very optimistic one. Moreover, the projects were among the things first described to us by the graduating seniors and in several cases were the basis for job offers. Project lore was everywhere on campus, from advertisements on bulletin boards, to recruiting efforts by juniors and seniors for freshmen to join with their projects, to transient antennas competing for space with frisbees on the lawn. Clearly these made up a key part of the intellectual excitement of the campus, and acted as nuclei for the small educational groups referred to earlier.

It would be easy to let down and consider this problem solved, but it will require hard work every year. Moreover its success offers an opportunity for supporting other parts of the program, and there must be some improvement in minimum acceptable levels. The first step we saw for quality control is that of having the students present reports on their projects to audiences of faculty, students, and members of the industrial community. (This presentation may be part of the Competency Examination to be discussed next.) Such a presentation could easily become pro forma, as the Defense of Thesis is in many colleges, so care must be taken in designing the format and incentives for listeners and for project participants to prevent such degeneration.

B. Competency Examination. This feature of the Plan has caused most discussion during the past year. There have been additional Faculty meetings on this matter since the time of the Panel's visit, apparently with considerable progress, but the feature remains a very difficult one. The ideal of an examination to measure competency rather than mastery of a collection of facts and algorithms, and thus to underscore the self-learning features of the Plan, is a fine one. Many Plan adherents understandably see this as the key feature of the Plan. But from the beginning there have been many who see it more as a comprehensive examination. Moreover a true competency examination is very hard to design with high validity and uniformity from student to student and from department to department. It must have such validity and uniformity if it is to be used as a final screen very late in the student's academic career.

It may be that this problem, like so many others we have worried about, will be solved, but I see the problem as a very fundamental one. (I am appending my comments of a year ago concerning the difficulties in various forms of examination, which I still feel pertinent.) It has seemed to many of us that some modifications of this procedure do not constitute abandonment of the Plan, but rather the needed corrections in the spirit discussed in Part [illegible] of this report. For one thing, it seems desirable for an examining or review committee to judge all aspects of the student's accomplishment at WPI -- particularly the project -- rather than just the few-day examination in deciding upon readiness for graduation. Then, by building questions around the two major projects rather than a short one thought up for the examination, there will be an opportunity to judge performance on something in which the student has invested a good deal of time and should have thought about deeply. This effort will also accomplish some of quality control for projects recommended earlier.

C. Intersession. Our Panel visited shortly after the first very successful intersession. This seemed to many of us one of the most imaginative features of the Plan, with faculty members teaching hobbies or exploratory subjects, and the students finding faculty members as persons rather than as mere specialists. But by the time we got to discussing this element it appeared to be decreasing in popularity, so we concluded that it might have been important in helping to establish the spirit necessary to begin the plan, but not essential in the long run. I suggested once that it might be an important experience for each generation of students, so that it could be repeated every three years or so, but not every year. Now, however, it seems to have settled down into a reasonable pattern, with about half the students and faculty participating, and many more students on campus because of the opportunity to work on projects. This is a very commendable success, particularly in view of the decay in intersessions in many other schools that tried them. I agree with George Pake's recommendation that a following Panel might look at this more carefully, trying to find the elements that can be passed on to other schools, and in helping to insure its continuing success as an element of the WPI experience.

D. The Seven-Week Term. This has been a feature discussed on many of our visits, and I'm sure one which will be analyzed by many of the panelists. I will consequently be brief to avoid unnecessary repetition. The goal of studying a few subjects in concentrated fashion for short periods has been tried in a number of experiments (in one extreme at Colorado College concentrating on a single course for a three week interval)* and undoubtedly works well for some subjects. Languages are among the skills often cited as suitable for complete concentration for limited periods. Other subjects seem to take more reflection, and thus correspondingly longer feedback periods. Of course one can put short periods together to make longer units where necessary. The attractive feature of relatively short blocks is the potential flexibility in using them either for concentration or for parts of a longer series, and for breaks in which students may take full time to work on projects. But to have all this potential flexibility available, the school will have to schedule a majority of offerings for each of the terms so that the student will not lose continuity by taking breaks in any arbitrary term. The number of such offerings then goes up rapidly as the number of intervals increases (I think something like the factorial of the number). Moreover there is a certain tare in the start-and-stop functions of the shorter terms, although these can be minimized by planning, say by registration for the entire year and then recording only changes from a planned program. Thus it seems to come down to a practical matter of weighing the advantages and the disadvantages, with much less concern than we first saw among either critics or supporters of the short terms.

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*Maxwell F. Taylor Jr. and James B. Levison, The Colorado College Plan - A Report of the Internal Evaluation Program, for the [illegible] 1970-74, Colorado Springs, Colorado May 1974.

E. Imaginative Use of Videotapes. Videotapes have been used both with IPI and conventional courses for the last several years, and several of us have observed their use in the libraries and laboratories. I have tried to watch the library use on each visit, and have the impression that use is increasing and that the medium is not becoming boring as has happened in some places. The key seems to be the convenience of the facility organized by Ken Scott, with the opportunity for instructors to stop by and record short supplements, reviews and lemmas without much fuss, and to record laboratory demonstrations with reasonable planning. The tapes are used, partly because they are short and partly because they may be stopped, repeated for note taking if it seems desirable to the student. I have watched mostly the individual use of the tapes. James Gibbons of Stanford, in describing his use of videotapes in M.S. programs, stated that groups of three to five students working together with tapes, stopping the tape to discuss difficult points, and having access to a tutor on some occasions (but not constantly) constitutes one of the best of the educational experiences he has worked with. I had seen some such groups in laboratories and tutorial sessions at WPI, but didn't give them enough attention since I had not heard Gibbons' analysis until after our last visit. It is possible that more of the TV consoles should be set up for the small group interaction as compared with individual viewing. In any event present uses of this medium constitute some of the best uses of educational technology I have seen.

F. Resources for the Plan. The question of resources for this ambitious change was mentioned earlier in the report. It is clear that some faculty members are working much too hard, although the load seems not to be distributed evenly (a common phenomenon in any academic environment). It now seems possible to make a better estimate of the total commitment than was possible when the Plan was just a plan, so the administration, the faculty, the faculty survey team, and the next Panel might try to put down some estimates concerning the amount of time required for each key element of the Plan (projects, competency examinations, intersessions, advising, normal course work, etc.) to see if the resources at all match the demands. At the same time, the extra resources from students (also mentioned earlier) might be examined more carefully to see if some of these inputs can be nurtured by better planning of institutional or environmental surroundings.

V Conclusions and Recommendations

As will be evident from the above discussion, my conclusions concerning the Plan agree almost entirely with those in George Pake's excellent summary. The most important ones have to do with the strengthening of projects, the reexamination of the Competency Examination, the continuing study of resources, and a special but somewhat relaxed look at the Intersession program. Other important academic matters have to do with the seven-week term, full exploitation of the consortium opportunity in Worcester, and the difficult question of the amount of stress to be placed on the graduate program, but I seem to have nothing to add to the obvious on these points. I have also mentioned the important role of the videotape system, and the suggestion that more group viewing stations be planned.

Our observation of the ingenuity, resiliency and dedication of administration and faculty in meeting the tremendous pressures to date gives us a great deal of confidence in the amount to be achieved by this experiment. As others have said, I have not seen a more ambitious undertaking in any project for educational innovation, nor one at any level carried out better. I think a lot can be learned from it, not by transporting the Plan in its entirety, but rather by careful study of the initial conditions, the surprises, and the corrective actions that were taken to ease the many pressure points. I am glad that some support will continue, including continuing study by a new Panel, for it is unrealistic to believe that an effort of this magnitude can become completely self-sustaining in three or four years.

Others on the Panel have noted than in the past three years we have come to feel ourselves a part of the Plan. I suppose in that respect we are less useful as objective evaluators, but I think it is some measure of the spirit of WPI, absolutely essential to carry off something of this magnitude.

The short project or group of tough problems is another mechanism possible for such an examination, and I believe one used at WPI. My experience with this was largely in the GE "Advanced Course" which was conducted entirely through such one-week projects. Like the oral, it is an extremely useful mechanism for obtaining a different kind of information from that found with conventional examinations. But it is extremly hard to find enough good projects of the correct scope and level of difficulty. It was common in the GE course I mentioned to find that in any one week a few of the best students (again judged by later performance) had started in the wrong way and hadn't made progress. And occasionally the problem was miscast so that it was either trivial or impossible. Here also the standards will vary widely from group to group, as will be evident, I think, if one group's exams are reviewed by each of the other groups.

Combinations of the above generally have greater validity than any one component alone, and such combinations are being used at WPI. But this is just where the time will become excessive if each exam is individually tailored, and well enough constructed to have the validity desired. Thus the Committee's recommendation, at least while experience in the validation of the examinations is being obtained. If worded as one of the requirements, with a Committee to review performance on all requirements in recommending graduation, it need not be seen as a major modification of the plan. I also recommend consultation with experts on the theory and practice of examinations to help in determining the best of the several possible forms, and the degree of validation needed, so long as it remains even a major component of the Plan.

Appendix - Excerpted from report of May 6, 1974 J. R. Whinnery
to Dean William R. Grogan

"Competency Examinations. The Committee recommended that the competency examination be graded and considered with other achievements of the four years in determining graduation from WPI, rather than be considered as an absolute gate. I feel very strongly on this matter. I first started worrying about it (as explained in my previous report) from the point of view of faculty load, but in the discussion it became evident that a much more fundamental point is the problem of developing an examination with enough validity to be useful as a binary gate for a student who has invested four years of work to that point. Although I don't intend to be an authority on examinations, I believe that it is not possible and would like to comment on the various forms of examination.

Written examinations can be made consistent in their results, provided the subject matter to be examined is defined. Even here, as the persons in Educational Testing Service will tell you, it requires a great deal of effort and sample testing to validate each question or problem of the examination. And in the end there is a high degree of correlation between the results and those of the few hundred written examinations (expressed through GPA) taken by the student in his career. The significance of the differences are still subject to debate, and must be studied in each case showing such a discrepancy. Construction of a range of validated examinations for a completely flexible curriculum would of course be a tremendous task.

Oral examinations are the most interesting and at their best give a different kind of information from that of the other types. The panel members gave their experiences with many bad Ph. D. orals. I have also given orals (often as an option) in undergraduate classes and found the same problems. Some of the best students (a value judgment validated by later performance in industry) simply "freeze" and can't think on their feet. A repeat of the examination increases the tension and often ends with worse results. Orals given by a panel are often marred by trick questions, or dominance by one member of the panel, or other psychological interplay between the panel and student or among the panel members themselves. Standards inevitably vary widely between various groups conducting the examinations. A common argument for the oral is that the candidate must learn to think on his feet and to present his conclusions orally. Granted that this is a highly desirable if not essential quality in graduates of any school, the oral examination is an artificial mechanism for demonstrating this as compared with a seminar on work done by the student. Moreover, if it is one of the absolute essentials for all graduates, attention must be given to developing this skill throughout the student's career.

APPENDIX

RESTRUCTURING UNDERGRADUATE EDUCATION
AT
WORCESTER POLYTECHNIC INSTITUTE

A Report To The Twenty-eighth Meeting
of the
Advisory Committee for Science Education
National Science Foundation
Washington, D.C.

March 6, 1975

By

William R. Grogan
Dean of Undergraduate Studies
Project Director

RESTRUCTURING UNDERGRADUATE EDUCATION
AT
WORCESTER POLYTECHNIC INSTITUTE

A Report To The Advisory Committee For Science Education Of The National Science Foundation

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Worcester Polytechnic Institute has undertaken a complete and systematic revision of its traditional approach to undergraduate science engineering education. The resulting educational program, known as the WPI Plan, is the product of two years of intensive planning and five years of implementation effort involving every member of the campus community. The program now involves 85% of the 2000-member undergraduate student body of whom over 95% are science or engineering majors. Next year (1975-76) 93% of the students will puruse their programs in accordance with the new WPI Plan requirements, and thereafter all students will be in the new program.

The National Science Foundation through its 1972 CoSIP award of $733,000 played a major role in enabling WPI as an institution to implement the restructured programs. The WPI Plan, and its implementation process are already the subject of considerable national attention.[1] There is every prospect interest will increase as the reports on the first three-year phase of program evaluation become available later this year.

This presentation will describe the scope of change at WPI and some of the more important features of the new program covering those areas receiving major NSF support namely, development of (a) the project system, (b) the advising system, (c) competency examinations and an overall evaluation of the program.

Background

Why Worcester Polytechnic Institute undertook the most drastic change in its 110-year old history could be the subject of a book itself - there was no crisis, not even administrative pressure. There was, however, in the faculty a gnawing dissatisfcation with the de-motivating rigidity of the traditional curricula; there was growing concern that science and engineering undergraduates were so constrained by the dictates of an impersonal lock-step system that their full development as thoughtful individuals was not being achieved. To those faculty who followed the careers of the graduates there appeared to be unreasonable discontinuity between the overall preparation of the students and the actual demands placed upon them as young professionals. No one ever questioned the need for a firm foundation in fundamentals, but beyond that, a number of paradoxical situations appear: A rigid academic program offered little opportunity for the student to assume responsibility for defining personal objectives; this responsibility became total immediately after graduation. Courses developed long, narrow corridors of knowledge; professional practice required integration of knowledge. The classroom experience was basically passive; professional practice required self-activation. In the academic setting, the student was usually an isolated learner, most of professional life involved personal interactions and shared experiences effectively communicated. A concern for the social implications of scientific and technological developments were almost non-existent. The presence of a certain discontinuity between the role of student and professional is natural and unavoidable; the concern at WPI was that the world of preparation and the world of practice were excessively disparate.

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[1] c.f. Appendix A (Summary of Presentations, Publications, and major news articles)

The WPI study began in 1968. First a strategic analysis evaluated every resource and constraint at the College and included an extensive evaluation of future needs for professionals in scientific and engineering careers. A Planning Committee of six faculty offered 14 alternative paths for the College to follow. After considerable analysis a statement of goals was adopted by the faculty and the trustees.

The goal statement[2] provided the cornerstone for the second development: the establishment of the degree requirements. The last step was the development of an academic support structure which would prepare students to meet the degree requirements.

In June 1970, the faculty voted to commit the entire college to a new approach to engineering and scientific education which promoted the concept of an individualized curricula for each engineering student. The program placed heavy emphasis on project-based learning and accomplishment. For the baccalaureate degree demonstration of competence through qualifying projects and competence examination is required. There are no specific course requirements but three years of successful work is required before the competency examination can be scheduled.

The Degree Requirements

The WPI Plan calls for the award of an academic degree upon demonstration of competence embodied in the four degree requirements which are:

1) A qualifying project dealing with a problem in one's major area of study (¼ year equivalent)

2) A qualifying project relating science and technology to societal concern and human need (¼ year equivalent)

3) A Sufficiency (minor) in an area of the humanities (½ year equivalent)

4) A Competency Examination in the major field of study (1 week duration).

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[2] From Worcester Polytechnic Institute Operational Catalog, 1975-76:

"It is the goal of the Worcester Polytechnic Institute to bring into the second century of its existence a new, dynamic version of its "Two Towers" tradition.

By means of coordinated programs tailored to the needs of the individual students, it is the fundamental purpose of WPI to impart to students an understanding of a sector of science and technology and a mature understanding of themselves, and the needs of the people around them. WPI students, from the beginning of their undergraduate education, should demonstrate that they can learn on their own, that they can translate their learning into worthwhile action, and that they are thoroughly aware of the interrelationships among basic knowledge, technolgical advances, and human need. A WPI education should develop in students a strong degree of self-confidence, an awareness of the community beyond themselves, and an intellectual restlessness that spurs them to continued learning.

Endorsed by the Faculty December 17, 1969."

Projects

The Major Qualifying Project (MQP)

The Project approach to learning was selected as a major vehicle for achieving the Plan's goals. To meet this degree requirement, the student must complete two projects, to each of which he must devote the equivalent of a quarter of a year's effort. One of the projects must deal with the students' major area of interest, while the other is intended to relate science and technology to societal concerns and human need. The first of these is known as the Major Qualifying Project (MQP), while the second has been designated the "Interactive" Qualifying Project, (IQP).

Projects are, of course, not new to WPI or to engineering and scientific education. The value of carefully supervised independent study is well established. The challenge to WPI in implementing the MQP requirement is not one, therefore, of concept of kind, but rather of scale and scope. After this year when transition of the Plan will be virtually complete, WPI will be graduating classes numbering between four and five hundred students each of whom will have completed the two qualifying projects. We have been able to test and adopt measures to minimize faculty load dislocations that otherwise might have occurred as a steady-state condition approaches in which twenty to twenty-five percent of all undergraduate activity is project-centered. Among these measures are consolidation of course offerings, changes in course format, increased use of technological aids, and active efforts to foster the formation of group projects rather than individual project efforts. An entirely new registration system was developed and is now operational.

The logistical problems involved in providing each of approximately 500 graduating seniors with two qualifying projects and, in addition to providing pre-qualifying project experience for underclassmen are indeed formidable. Of course there are many on-campus projects, especially in the sciences, but WPI has tried to provide students with as many opportunities as possible for off-campus MQP and IQP work. A special administrative unit for project operations has been established. A central on-campus project center was constructed to augment departmental facilities and provide a support base for interdisciplinary projects, and a wide variety of off-campus arrangements developed. Three levels of off-campus project sites have been developed:

1) Over 100 project sites[3] with intermittent activity where students execute specific projects as the mutual need of the company and WPI arise;

2) Nineteen project sites[3] with sustained activity where one or more faculty advisors are working with students continuously on a variety of projects, some extending over a period of years; and,

3) Six Project Centers[3] (sometimes called Internship Centers) each of which has a formally appointed WPI Director and an on-site counterpart from the company or institution involved.

At these Project Centers WPI usually maintains a permanent office. A wide variety of multidisciplinary projects are coordinated by the Director of the Center but with specific projects under direct supervision of faculty advisors from the disciplines involved. Five centers are within commuting distance; one, in Washington, D.C. is a residential site. In all cases project activity is a direct extension of the academic program, the work performed under faculty direction for academic credit while pay is not acceptable. Direct expenses are usually paid by the sponsoring institution.

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[3] Appendix B contains a listing of the specific sites and centers.

A fine example of a highly successful Center is that at St. Vincent Hospital in Worcester, where over the last two and a half years 67 students have been involved in 28 different projects working with 11 WPI faculty advisors and 14 hospital advisors.

The following table summarizes the many types of multidisciplinary interactions at the St. Vincent Center.

Participating Hospital Functions	Participating WPI Disciplines
Cardiac Catheterization	Biomedical Engineering
Cardiology	Chemical Engineering
Hematology	Electrical Engineering
Clinical Engineering	Computer Science
Hospital Facilities	Chemistry
Pathology	Life Sciences
Plastic Surgery	Management Engineering
Radiology	Mechanical Engineering
Respiratory Diseases	Materials Science
General Surgery	Physics
Vascular Research	

The interest and cooperation from the industrial community and governmental agencies at all levels has been outstanding. The project effort at WPI has grown from 63 registrations in the fall of 1972 to 535 last fall with an expected steady-state registration of about 720 per term next year. In spite of this increase in activity there appears to be no shortage of sound project opportunities and there is currently a waiting list of potential industrial sponsors.

In summary there appear to be four essential ingredients for successful and sustained off-campus project operation:

1) An interested faculty advisor and cooperative liasion personnel.

2) Carefully prepared and documented student proposals acceptable to advisor and liasion before work is initiated or resources committed (much learning takes place here.)

3) Requirement of periodic written progress reports with at least one formal oral preliminary report.

4) High final report standards both written and oral, with sponsor evaluation an important factor in grading.

The "Interactive" Qualifying Project (IQP)

Courses in social science have often been required in science and engineering curricula. While valuable in themselves, there was no experiential component which brought into physical reality for the student the social, political, or humanistic dimensions of their technological world. Each graduate at WPI is now expected to qualify in a field project which is designed to develop a greater awareness of the relationship between science and engineering on one hand and social concern and human values on the other. This component of the WPI program is highly experimental, but has proven to be one of the most fascinating.

The Objectives of the IQP can be summarized as follows: (1) to create through experiential education an awareness of socially related technological interactions; (2) to enable the identification of socio-technological systems, subsystems, and their linkages; (3) to cultivate the habit of questioning social values and structures; (4) to develop and integrate the skills of evaluation and analysis; (5) to provide methods for assessing the impact of technology; and (6) to encourage the recommendations of policy.

The Project Center is Washington, for example, is primarily devoted to IQP work. The Center accommodates 80 students. Following a preparation period on campus, each student resides in Washington for seven weeks involved with project field work in governmental and private agencies; this precedes a report writing phase back on campus. A summary of the sponsoring Washington agencies and the titles of projects undertaken with them is contained in Appendix C.

The Humanities Sufficiency

The "broadening" requirement of a traditional science or engineering program usually calls for the student to take some distributed coursework in the humanities. The WPI Plan proceeds on the underlying assumption that it is better to have a deeper understanding of the humanities in at least one area than to have a surface view of many. To that end, the WPI student must develop a specific humanities minor (sufficiency). He selects five thematically related humanities courses, and in the sixth activity the student must conduct an independent study developing a unifying theme for his selected courses. The thematic relationship clause does not constrain the student to courses of one type, e.g. history courses. Should he wish to concentrate on a particular period in history, he may take, as well as history courses dealing with that period, courses in English which deal with the literature of that period. Alternatively, the student may prefer to develop the equivalent of the course material entirely on his own, through independent study, in which case he would satisfy the degree requirements by successfully passing a Sufficiency Examination. At the present time WPI students are developing sufficiences (or minors) in History, Philosophy, Languages, Literature, Music and Drama. The humanities program has been strengthened considerably through assistance of the National Endowment for the Humanities based on a proposal that was carefully developed to complement the NSF support for the sciences.

The Competency Examination

Four weeks a year, between the seven-week terms, are assigned exclusively for student competency examinations. The student's competence in his major field is tested through complex problems - something akin to what he or she would be expected to do as a baccalaureate graduate in the chosen major. The student is assigned one or more problems and has access to reference materials, computer facilities, library, laboratories and faculty. At the end of the assigned period each student reports back to the assigned examination committee with a written report. An oral examination follows in which the method of attack, soundness of fundamental principles and alternate approaches to the problem are discussed. The competency examination is designed to test for an understanding of methods, resources, fundamental principles and theories, as well as application of current techniques in the field.

Despite a greal deal of effort, some of it supported by NSF, much remains to be learned about this type of competency measurement and developmental work continues in this area.

The Support Structure

The Advising System is of critical importance as each student works with his or her advisor developing a personalized curriculum. Each student must have a firm curricula planned ahead for one year, and a tentative one beyond that. Incremental changes may be made at the opening of any of the seven-week terms. Each term a student normally carries three courses or an equivalent level of project work. Considerable counseling is also needed in the selection of appropriate project activities, the humanities sufficiency, and, of course, the timing of the competency examination. The organization of the large amount of information needed to support this system has proceeded very well - a completely new registration system has been developed to accommodate the five terms per year, the individualized curricula, the new grading system (Distinction, Acceptable, No Record) and of course the many hundreds of project combinations. An on-line computer-controlled registration system has been developed which assists program planning for an entire academic year, yet allows opportunities for regular schedule review and revision. Current and projected student schedules, transcripts and degree status are instantly available on remote CRT terminals at the office of the Registrar and Dean of Academic Advising.

Supportive of all instructional modes is an extensive and continually developing capability in various media, including a TV studio with taping facilities, closed circuit television for all campus buildings, a time-shared remote access computer with over twenty teletype and CRT remote terminals located throughout the campus including 24-hour accessibility in the dormitories, a hands-on video tape viewing capability with twenty video-recorder viewing stations, an extensive library of specially prepared interactive computer programs, and a modern, spacious library holding some 120,000 books, periodicals, and non-print materials as well as a 250,000 item collection of technical reports and microforms.

The use of TV tapes has been highly effective in releasing faculty time to accommodate the other demands of the Plan. To date over half of the entire faculty have taken advantage of a highly effective TV taping facility to prepare tapes on everything from equipment orientation demonstrations to special course topics that often cause difficulties. To date over 700 TV tapes have been made by WPI faculty and tapes are integrated supplements to at least 60 on-going courses. The central viewing facility registered over 14,500 student viewings last year, up from 3,100 just two years ago. This does not include the use of departmental and laboratory viewing sites. A large program is now underway to expand the use of TV tapes in laboratories to save staff time in introducing students to a wide variety of techniques and methods of equipment operation.

Foundation Support

A number of private foundations have joined the National Science Foundation and the National Endowment for the Humanities in support of the WPI Plan implementation program. Among these have been the Carnegie Corporation in support of course revision, the Sloan Foundation in support of development of the social sciences and preparation of faculty to advise socially-oriented projects, and the Mellon Foundation in support of the new humanities program. The early recognition of the innovative qualities of the WPI program by the National Science Foundation has most recently been complimented by the award of a Venture Fund Grant to WPI by the Ford Foundation.

Evaluation

There are currently underway three formal NSF sponsored evaluations of the effectiveness of the WPI Plan:

1. A panel of nationally-known educators and industrialists[4] which visits the campus twice a year,
2. A study of faculty and administrative changes both attitudinal and organizational caused by the Plan, carried out by Harvard University consultants. The factors under consideration in the faculty/administration study are:

   A. Professional Satisfaction and Growth
   B. Perceptions of Quality of Student Learning
   C. Perceptions of Rewards, Effort and Equity
   D. Instrinsic Satisfaction
   E. Stress and Overload
   F. Interference Items
   G. Patterns of Interaction

With the assistance of grant extension from NSF awarded in May 1974, the study has been extended to include two comparison colleges. Both colleges have much in common with WPI and have been most cooperative in providing a base for parallel studies.

3. The effect of the Plan on students carried out by Dr. Cohen of the Education Development Center (EDC) in Cambridge, Massachusetts. This investigation also includes a comparison study of engineering students at other colleges which have not undergone the change seen at WPI.

The evaluation of the students has centered around a study of the following factors:

   A. Scientific and Engineering Competence
   B. Self-Concepts
   C. Attitudes and Educational Goals
   D. Background and Abilities
   E. Characteristics of Learners

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[4] The Advisory Panel consists of the following:

Dr. Lee Harrisberger, Dean of Science and Engineering, University of Texas of the Permain Basin

Dr. Bruce Mazlish, Professor of History, Massachusetts Institute of Technology

Dr. George E. Pake, Vice-President Research, Xerox Corporation

Dr. Kenneth G. Picha, School of Engineering, University of Massachusetts

Dr. Eugene D. Reed, Executive Director, Bell Telephone Laboratories Ocean Systems Division

Dr. David Riesman, Department of Sociology, Harvard University

Dr. John R. Whinnery, Department of Electrical Engineering, University of California

It is planned to continue the study of the students through their early professional lives, thereby completing what promises to be the most comprehensive study of the process and effects of change in a college of science and engineering available to the academic community to date.

The Advisory Panel has submitted an individual report following each visit. We expect a combined report will follow the Panel's sixth and final visit in April, 1975. The final reports on the faculty and student evaluations will be available in the file.

The EDC studies already show that the desired developments of self-confidence, of willingness to assume responsibility, and of greatly increased social consciousness are indeed taking place in WPI students.

The qualifying project work, a major component of the WPI Plan and the major development supported by the NSF grant is proving to be an extremely effective educational concept. The students are responding to the requirement with enthusiasm faculty involvement is over 90% and despite the mind-boggling logistical problems the program is developing on schedule.

Off-campus project sponsors have also assisted in the evaluation. Of approximately 200 project questionnaires studied in January 1975, it was encouraging to note that the sponsors felt 63% of the work achieved expectations, 26% exceeded expectations, while only 4% were in the combined categories of "fair" or "expectations not achieved." Only 3% of the participating sponsors said they would prefer not to continue in the program while 43% wished to increase their commitment, the remainder being satisfied with the present level of activity. From the students' returns, it is interesting to note that 46% of the off-campus liasion personnel were rated as "outstanding" while 46% of the students also said that they would be happy to be associated with their sponsor when they graduated.

Questionnaires received by Dr. Cohen's group from students and sponsors indicate that both groups feel a great deal of learning is taking place. In rating their own experimental expertise at the start and at the end of the projects, the 70 students replied as follows:

	Outstanding	Good	Fair	Poor
At Start	5%	28%	49%	18%
At End	31%	63%	6%	0%

In rating personal learning 52% of the students listed "Outstanding" with 37% as "Good".

In rating their own performance and achievement the students listed themselves 19% "Outstanding" and 65% "Good" while sponsor ratings are running 26% "Outstanding" and 63% "Good".

The evaluation of activities of WPI's Plan students when they become alumni will, of course, be the ultimate test of the effectiveness of the WPI Plan in achieving the educational goals it was designed to achieve.

APPENDICES

APPENDIX A

There follows a partial summary of papers, publications and news stories published to date:

JOURNALS AND NEWSPAPERS

AIAA Student Journal. Hazzard, George W. "A New Breed of Leader... The Engineer." December 1973.

Business Week. "Engineers Learn By Doing." Reprinted from the August 31, 1974 issue of Business Week by special permission © from McGraw-Hill, Inc.

Change: The Magazine of Higher Learning. Monroe, Sylvester. "WPI's Program for Technological Humanists." Vol. 6, No. 5; June 1974. Reprinted with permission from Change.

The Christian Science Monitor. Gehret, Kenneth G. "Free But Accountable; Engineering Students Chart Own Course." Reprinted by permission - The Christian Science Monitor © 1971.

Engineering Education. Hazzard, George W. "The WPI Plan: New Directions for Engineering Education." Vol. 61, No. 6, February 1971. Reprinted from Engineering Education © 1971 American Society for Engineering Education.

Los Angeles Times. Trombley, William. "Tech School Students Plan Program." September 7, 1972. Reprinted with permission. Copyright, 1972, Los Angeles Times.

Mosaic Magazine. "It's Your Education"; Three Approaches To Giving More Responsibility To College Students For Their Own Learning. Vol. 4, No. 3 Summer 1973. Reprinted with permission from Mosaic Magazine published by the National Science Foundation.

The New York Times. Hazzard, George W. "Engineering Schools Try To Mold A Broader, More Humanistic Graduate." January 8, 1973. Reprint.

The Wall Street Journal. Metz, Tim. "A College Throws Out The Curriculum." October 2, 1970. Reprinted with permission.

Worcester Telegram. Swan, Gary E. "WPI Plan Bears Fruit 4 Years After Inception." March 3, 1973. Reprinted with permission.

Worcester Telegram. "WPI Applicants To Admit Themselves." August 13, 1972. Reprinted with permission.

Worcester Telegram. Foster, Robert A. 'The Plan' At WPI Works. Reprinted with permission. July 5, 1974.

PRESENTATIONS AND PUBLISHED PAPERS

Chalabi, A. Fattah. "New Interdisciplinary Program in Construction Management at WPI." Presented at ASCE Conference on Civil Engineering Education, Vol. 1, Part 2, February 1974. Published by ASCE, including description of WPI Plan.

Chalabi, A. Fattah.. "PSI Courses in Elementary Mechanics at WPI." Accepted for publication in the proceedings for the First National Conference on Personalized Instruction in Higher Education, Washington, D.C. (New teaching methods under the WPI Plan.)

Grogan, William R. "Implementing Educational Change." Presentation at the National Science Foundation CoSIP Director's Meeting, March 21, 1974. Washington, D.C.

Grogan, William R., Scott, Kenneth E., Peura, Robert A., Demetry, James S. "The WPI Plan: A Comprehensive Historical Report." July 16, 1974. International Conference on "Frontiers in Education," London, England. (Also presented at the ASEE 1974 Annual Meeting in Troy, N.Y.)

Grogan, William R., Silva, Armand J. "WPI Plan - From Concept to Reality." Paper presented at ASCE Conference on Civil Engineering Education, February 28-March 2, 1974. Ohio State University.

Grogan, William R., Scott, Kenneth E., Peura, Robert A., Demetry, James S. "The WPI Plan To Achieve Engineering Expectations." College-Industry Conference, February 12-14, 1975, New Orleans, Louisiana.

Hazzard, George W. "The College Student: A Modern Luther?" Sermon given at the First Unitarian Church. August 2, 1970.

Hazzard, George W. "Common Problems of Technical Colleges & Businesses." May 5, 1970. Forgoing Industry Educational and Research Foundation Talk.

Hazzard, George W. "Engineering as a Liberal Education." May 1, 1971. Convocation dedicating the Center for Science and Engineering Union College, Schenedtady, New York.

Hazzard, George W. "Higher Education's Consumer Response Leads Industry or Modern Technical Education: A Challenge to Cooporate Management." January 17, 1974. ELFUN Talk (GE).

Hazzard, George W. "Technical Education: WPI's Response to the Future." October 25, 1971. Talk given to the American Society of Mechanical Engineers, Management Executives Conference.

Hazzard, George W. "The Technical Humanist: A New Professional-Liberal Education." February 26, 1974. American Association for the Advancement of Science, 140th Meeting, San Francisco, California.

Keil, Thomas. "The WPI Plan." June 21, 1974. American Association of Physics Teachers Meetings. Boone, North Carolina.

Keil, Thomas. "The WPI Plan." February 1, 1973. American Association of Physics Teachers Meetings, New York, New York.

Keshaven, Kris, Lutz, Francis, and Smith, Richard. "WPI's Environmental Systems Study Program." Presented at ASCE Conference, February 1974. Ohio State University.

Peura, Robert A., et al. "Organization and Function of Hospital Biomedical Internship Center." A paper submitted to the March 1975 Special Issue on Education and Employment in Biomedical Engineering. IEEE Transactions on Biomedical Engineering.

Scott, Kenneth E., Peura, Robert A., and Demetry, James S. "The WPI Plan: A Case Study." (A reproduction with permission from the American Society for Engineering Education of Chapter 10 from the monograph Individualized Instruction in Engineering Education prepared by Lawrence P. Grayson and Joseph M. Biedenback and copyrighted by the American Society for Engineering Education.)

Wilbur, L.S. "Lower Power Reactor Utilization." November 1970. University of Florida. (Described WPI Plan as part of presentation.)

Wilbur, L.C. "Utilization of a Lower Power Reactor as a Multi-Purpose Facility." February 1972. Texas A & M. (Included WPI Project Applications.)

Zwiep, Donald N. "Engineers as Inarticulate in their Oral Expression. What are we doing about it." June 1973. ASEE Annual Meeting, Iowa State University. (This video tape presentation was repeated at the 1974 Annual Meeting of ASEE, Academas Program, by special request.)

Zwiep, Donald N. "Projects Administration." June 1972. ASEE Annual Meeting, Lubbock, Texas.

Zwiep, Donald Z. "The WPI Plan - The Operational Phase of a Unique Approach to Engineering Education." October 8, 1974. Engineering College Placement Officers Fall Conference, Bretton Woods, New Hampshire.

In addition to the list above, WPI has a file of over 250 written inquires about the program and representatives from approximately 30 colleges in the United States, Canada and Europe have visited WPI to observe the program in operation.

APPENDIX B

OFF-CAMPUS SITES FOR WPI PROJECT ACTIVITY

I. WPI Off-Campus Project Centers

Digital Equipment Corporation (Maynard)
Norton Company (International Headquarters, Worcester)
Small Business Administration (Boston)
St. Vincent's Hospital (Worcester)
U.S. Army Laboratories (Natick)
WPI Project Center, Washington, D.C.

II. WPI Off-Campus Project Sites with Sustained Long-term Activity

Central Massachusetts Regional Planning Commission
Clapp Laboratories
Crompton Knowles Corporation
Data General Corporation
General Electric Company (Fitchburg)
General Electric Company (Schenectady)
Massachusetts Juvenile Court System
Memorial Hospital Worcester
New England Electric Systems
New England Sound and Communication, Inc.
Pratt & Whitney Aircraft Corporation
Sprague Electric Company
Worcester Alternative School
Worcester County Jail
Worcester Foundation for Experimental Biology
Worcester Science Center
Wyman Gordon Company

III. Project Sites where WPI Projects took place Academic Year 1974-75

American Optical (Framingham, Mass.)
                 (Southbridge, Mass.)
American Telephone & Telegram
Army Materials & Mechanics Research Center
Astra Pharmacetical Company
Auri-Nil Industries
Belmont Street Community Center
Boy Scouts of America
Cape Cod Planning Commission
Caterpillar Tractor Company
Central Massachusetts Lung Association
Central Massachusetts Office of Planning & Community Development

Chandler Street Junior High School
Chicopee High School
City University of London (England)
Connecticut Department of Community Affairs
Combusion Engineering Corporation
Corporation of Engineers (Waltham, Mass.)
Department of Commerce (Washington)
Department of Health, Education & Welfare (Washington)
Department of Housing & Urban Development (Washington)
Department of Transporation (Washington)
Doherty High School
Drake and Associates
Electric Boiler Corporation
Environmental Protection Agency.
Foxboro Company
Friendly House, Inc.

Project Sites (Continued)

Friends Select School
Great Brook Valley
Hammond Plastics, Inc.
Harvey & Tracey Associates
Heald Machine Company
Hewlett Packard, Inc.
Hogan Regional Center
Honeywell Corporation
Intercontinental (West Boylston, Mass)
Jamesbury Corporation
Laster Conservation Commission
Liberty Mutual Research
Lincoln Laboratories (Bedford)
Loomis School
Lowell Corporation
Massachusetts Bicentennial Commission
Massachusetts Control District Air Pollution
Massachusetts Department of Community Affairs
Massachusetts Department Natural Resources
Marian High School
Marlboro Youth Center
Metropolitan Education Council Organization
Mirlin Corporation
Multifoam Inc.
Nashua River Watershed Association
Natick High School
National Association of Manufacturers
National Science Foundation
New England Congressional Caucus (Washington)
New England Research Corporation
New Haven School System
Nipmuc Regional High School
Norton High School
* Old Sturbridge Village
Oplex Corporation
Paxton Center School
Public Technology Incorporated
Riley Stoker Corporation
Rural Neighborhood Association
Salisbury Pond Task Force
Sanders Associates (Nashua, N.H.)
South Eastern Regional Planning & Economic Development Commission
Shrewsbury Conservation Commission
Shrewsbury High School
Society of Plastic Engineers
State Mutual Life Assurance Company
St. John's High School
Talcott M + N Science Center
Taylor and Fenn Incorporated
Thermo Electron Corporation
Thom McCan, Incorporated
Town Manager's Office (Sutton, Mass.)
Town of Holden Recreation
Town of Holden Planning Board
Transporation Systems Center (Cambridge, Mass.)
United Engineers and Construction
Venerini Academy
*Office of Planning & Community Development (Worcester)

Project Sites (Continued)

Veteran's Administration
Water Resources Commission of Massachusetts
West Boylston Junior Senior High School
West Hartford Connecticut (Town Manager's Office)
Western Electric Company
Weyerhauser Paper Corporation
Worcester Airport
Worcester Boys Trade School
Worcester Bus Company
Worcester City Manager's Office of
    Planning & Community Development
City of Worcester (City Hall)
Worcester Conservation Commission
Worcester Control Corporation
Worcester County Hotline Organization
Worcester Department of Public Works
Worcester Fire Prevention Bureau
Worcester Police Department
Worcester Telegram & Gazette
Wright Steel Corporation
UniRoyal, Incorporated
Yankee Atomic & NE Power Research

APPENDIX C

PROJECTS AT THE WASHINGTON CENTER 1974-75

PROJECT TITLE	STUDENT(S)	SPONSOR
"Analysis of Energy Legislation"	George Hefferon Robert Sentaken Barry Tarr	National Association of Manufacturers
Bi-Centennial/Civil Defense	Sid Formal Tom May	District of Columbia Civil Defense
Bi-Centennial/Civil Defense	Robert Hart John Diachenko	District of Columbia Civil Defense
"Coal Conversion and Clean Air Act Modification"	Val Danos	National Association of Manufacturers
Construction Management	Kevin Hastings H.W. Fairbanks	Public Technology, Inc.
"Coordination of Legislative Analysis"	Brian Barnoski	National Association of Manufacturers
"Determination of the Feasibility of Wastewaster Reuse"	William Mullen	Public Technology, Inc.
"Development of Techniques for Quantifying the Technological State of An Industry"	Ray Cibulskis John Gerstenlauer Martin Kristy James O'Neill	Department of Commerce
"Development of Techniques for Quantifying the Technological State of an Industry"	Ginny Giordano Duncan MacIntosh Charles Moulter	Department of Commerce
Energy and the Coastal Zone	Morris Weisman Robert Jamieson Mario Wunderlich	Council for Environmental Quality
Energy/Minerals Impacts	Wayne Elliott Carey Lazerow	National Association of Manufacturers
Historical Analysis of U.S. Energy Policy	Brian Young John Mangiagli John Manning Chuck Nienberg	Institute of Electrical and Electronics Engineers, Inc.
Impact of Environmental Constraints on an Industry	Tom McAloon Paul Grogan Ray Robey	National Association of Manufacturers
Impacts Across Industries of Energy Availability	Ed Fasulo Charles Lauzon	Department of Commerce
Impact of Mandatory Energy Conservation, etc.	Perry Griffin Mark Israel	Department of Commerce
"Intermodal Freight Terminals"	Steve Divoll Chris Ford John Forster Paul Wheeler	Department of Transportation
"Legislative Analysis of Impending Legislation for the National Association of Manufacturers"	Robert Birnberg	National Association of Manufacturers

Washington Projects (Continued)

PROJECT TITLE	STUDENT(S)	SPONSOR
"More Federal R & D Money for New England? An Attempt to Determine the Energy Related Project Capabilities of Some New England Industries"	Ed Griffin Oliver Smith	New England Congressional Caucus
"Municipal Applications of Cable TV"	Al Bowers Barry Siff Richard Weaver	Public Technology, Inc.
"Municipal Applications of Cable TV"	Tom Colp James Hohorst	Public Technology, Inc.
Product Defect Identification Analysis	Tom Stowe Richard Escolas John Moroney	Consumer Protection Safety Commission
"Research Applied to National Needs"	John Casey Ann Madera David Reid	National Science Foundation - Research Applied to National Needs
Road Pricing, etc.	John Griffiths	Federal Highway Works Administration - Department of Transportation
Safety of Portable Space Heaters	Mike Menesale Joe Martowski	Consumer Protection Safety Commission
"Space Vision: A New Concept in Education"	David Eves Glenn Guglietta	National Institute of Education - HEW
Utilization of Research Applied to National Needs	Tom Vaughn Daniel Garfi	National Science Foundation - RANN
Water Quality Measurement	William Booth Paul Carubia	Council for Environmental Quality
"What is a House?"	John Aubin Steve Borys Noreen Pirog Dave Williams	National Science Foundation PSAB-HUD